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PROCEEDINGS

OF THE

AMERICAN SOCIETY OF AGRONOMY

VOLUME 4

1912

PUBLISHED BY THE SOCIETY
1913

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PREFACE.

Volume 1 of the Proceedings covered the years 1907–1909, inclusive. It contained thirty-nine of the sixty-nine papers presented at the first four meetings, seventeen having been otherwise published and thirteen withdrawn for various reasons. The index for volume 1 will be found in volume 2.

Volume 2 covers the year 1910. It includes fifteen of the twenty papers presented at the Washington meeting and also one paper subsequently submitted for publication.

Volume 3, for the year 1911, contains nine of the sixteen papers presented at the annual meeting at Columbus and also five others later submitted for publication. The remaining seven papers presented at the annual meeting were withdrawn for various reasons. Volume 3 contains a considerable increase over volume 2 in the number of pages and of illustrations.

Volume 4 contains a total of twenty papers. Thirteen of these result from the special summer meeting held at Lansing, Mich., on July 11, 1912; six from the fifth annual meeting at Atlanta, Ga., on November 11th and 12th, 1912; and one was submitted independently. Of the thirteen papers from the Lansing meeting, eight were presented before the Society and five appeared only on the printed program. Of the six resulting from the Atlanta meeting, four were presented before the Society and two were presented by title on the program.

The publication of an annual volume of Proceedings will be discontinued with this volume. Early in 1913 the Society will begin the publication of a journal, quarterly at first and more frequently when circumstances warrant. An editorial board for the journal has been selected by the executive committee of the Society. The standing committee on publication will be discharged automatically on the publication of the present volume.

Respectfully submitted,

C. V. Piper, *Chairman.*
Carleton R. Ball,
T. Lyttleton Lyon,
Committee on Publication.

BUSINESS SECTION.

REPORT OF THE SECRETARY FOR 1912.

The principal lines of secretarial effort since the fourth annual meeting have been: (1) Increase in membership; (2) prompter publication of our PROCEEDINGS, and (3) increased sale of the three volumes of the PROCEEDINGS to libraries and members. A considerable degree of success has been attained along all three lines. The steady growth and progress of the Society makes the work of each succeeding year heavier than that of the year before. These activities have required the writing of 598 personal letters in addition to numerous circular letters sent out. It is a pleasure to report here the valuable assistance received from Miss Mary E. Holland, without which the work would have been much hampered. While not all have been accomplished that was hoped and planned, it is a matter of gratification that during this fifth year the Society has steadily increased in strength, influence and prosperity.

1. FUNDS COLLECTED BY THE SECRETARY.

Moneys have come to the Secretary chiefly from two different sources, namely, dues of new members and revenue from the sale of the PROCEEDINGS. Below is given a classified list of the funds all of which have been transferred to the Treasurer, receipted for by him, and included in his annual report.

CLASSIFIED RECEIPTS AND DISBURSEMENTS. JULY 25, 1911, TO NOVEMBER 5, 1912.

Receipts.

To reprints for authors		$ 43.19
To dues collected (itemized list appended):		
1 arrearage for 1910	$ 2.00	
57 new members for 1911 at $2.00	114.00	
4 arrearages for 1911 at $2.00	8.00	
29 new members for 1912 at $2.00	58.00	
1 arrearage for 1912 at $2.00	2.00	
1 advance for 1913 at $2.00	2.00	186.00
To PROCEEDINGS sold:		
65 copies of Volume 1 at $2.00	$130.00	
29 copies of Volume 1 at $1.25	36.25	
73 copies of Volume 2 at $1.50	109.50	
16 copies of Volume 2 at $1.00	16.00	
28 copies of Volume 3 at $2.00	56.00	
13 copies of Volume 3 at $1.50	19.50	367.25
224		
Total		$596.44

Disbursements.

December 13, 1911, by check to Treasurer McCall	$ 82.00	
December 20, 1911, by check to Treasurer McCall	43.19	
January 16, 1912, by check to Treasurer McCall	90.50	
April 16, 1912, by check to Treasurer McCall	86.50	
July 13, 1912, by check to Treasurer McCall	117.00	
October 1, 1912, by check to Treasurer McCall	102.00	
October 31, 1912, by check to Treasurer McCall	59.25	
November 5, 1912, by check to Treasurer McCall	16.00	$596.44
Balance on hand		$ 0.00

2. MEETINGS.

The Society has held seven meetings, one for organization, four annual and two summer meetings. The organization meeting was held in Chicago, the annual meetings in Washington, Omaha, Washington and Columbus, while the two summer meetings have been held at Ithaca and Lansing in connection with the sessions of the Graduate School of Agriculture in 1908 and 1912.

As noted, one meeting has been held already this year. This summer meeting occurred on July 11, 1912, at Lansing, Michigan, during the sessions of the Graduate School of Agriculture. The meeting was an interesting one and a considerable number of members were present. The titles for 19 papers were submitted and 9 papers were actually presented. Most of them will appear in Volume 4 of the PROCEEDINGS. The present meeting is the eighth serial and fifth annual meeting of the Society and its program contains 14 titles. Two more titles were received too late for insertion.

The question of the number, time and nature of our future meetings is deserving of the most careful consideration. The recent action of the Executive Committee of the Association of Agricultural College and Experiment Stations in voting to hold their meetings this year, not at Washington as heretofore in the even numbered years, but at Atlanta, remote from any agricultural college or experiment station, has profoundly and unfavorably influenced the proposed affiliation of agricultural organizations.

However, without regard to the place and time of holding the annual meetings of the future, it seems very desirable that we hold additional special meetings whenever feasible. It may be best to hold two or three of these in different sections or regions of the country in the same year. For instance, one might be held in the Cotton-belt States, one in the northeastern States, one in the upper Mississippi Valley, one in the Great Plains area and one west of the Rockies. In this way nearly all the members would have opportunity to attend at least one meeting each year. This would serve to bring out many good papers, to increase the interest in and the value of the Society and to build up its membership to a point where still greater things could be safely undertaken. Such regional special meetings could reasonably be held in connection with gatherings of scientists where a large number of agronomists are ordinarily accustomed to meet. Some of the meetings of this character are the National Corn Exposition, the American Association for the Advancement of Science, the biennial Graduate School of Agriculture, the National Irrigation Congress and the International Dry-Farming Congress, while there are still others of similar nature though smaller size.

3. MEMBERSHIP OF THE SOCIETY.

Comparative Statistics.

In 1910 46 new members were received and at the end of that year the Society had a paid membership of 167 (since increased by 1 renewal). In 1911 there were 71 accessions and 2 resignations, making a net gain of 69 members and increasing the total number to 236. During 1912 7 members have lapsed from membership through arrears for dues, and (to November 5, inclusive) there have been 33 new members and 2 renewals added, making a net gain of 28 members and a total membership of 264, which will be considerably increased before the end of the year.[1]

Membership taken for the year 1912 entitles the holder to the Proceedings resulting from the summer meeting held at Lansing and the annual meeting now in progress. For this reason a number who join within the next few weeks will elect to take membership for 1912 in order to obtain Volume 4 without further effort.

There are yet over 300 men in North America eligible to active membership in our Society. The 200 mark in membership was passed during our last annual meeting. The 300 mark is now just before us. A year ago your secretary suggested that the goal be set at 400 members for 1912. I would now say, let us set the goal at 500 for 1913 and work steadily and strongly toward that mark.

New Members, 1912.

Adams, E. L.
Ayrs, O. L.
Ball, Wilbur M.
Barker, Joseph F.
Barre, H. W.
Brown, J. Stanford.
Buell, T. W.
Chappelear, Geo. W.
Clark, J. Allen.
Coleman, L. C.
Conner, A. B.
Cromer, Otis.
Donaldson, N. C.
Engle, C. C.
Evans, Robert J.
Ferguson, A. M.
Firor, Guy W.
Gaines, E. F.
Garren, G. M.
Gernert, W. B.
Gilmore, John W.
Haskell, S. B.
Holtz, Henry F.
Hungerford, DeF.
Hunnicutt, B. H.
Hutchison, C. B.
Jodidi, Samuel L.
Jones, J. W.
Keitt, T. E.
Khankhoje, Pandurang.
Krause, Franz E. F.
Long, David D.
Lubchenco, Alexis E.
McFetridge, Wm. L.
McHenry, Norris.
Mackintosh, R. S.
Morgan, G. W.
Morrison, J. D.
Newton, Robert.
Oakland, Irwin.
Olson, George A.
Pammel, L. H.[2]
Porter, W. R.
Rast, Loy E.
Raymond, L. C.
Robbins, F. E.
Robert, J. C.
Roberts, John M.
Sherwin, M. E.
Smith, J. Warren.
Southwick, Everett F.
Warburton, C. W.
Wascher, F. M. W.
Welton, F. A.
Wermelskirchen, Louis.
Wheeler, W. A.
Williams, Chas. Burgess.
Wilson, Frank T.
Winsor, L. M.
Woodworth, C. M.
Worsham, W. A., Jr.
Wright, Chas. Shannon.
Yoder, P. A.

[1] At the close of 1912 the membership record stood as follows: Old members at beginning of year, 236; lapsed, 7; resigned, 1; renewals, 5; new members, 62; net increase, 59; total membership at close of calendar year, 295.

[2] Renewal.

List of Members, with Addresses.

Adams, E. L., U. S. Cereal Field Station, Biggs, Cal.
Adams, G. E., Experiment Station, Kingston, R. I.
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Alway, F. J., Experiment Station, Lincoln, Nebr.
Atkinson, Alfred, Experiment Station, Bozeman, Mont.
Ayrs, O. L., Care Tennessee Coal, Iron and R. R. Co., Birmingham, Ala.
Babcock, F. R., Experiment Farm, Williston, N. Dak.
Ball, Carleton R., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Ball, Elmer D., Experiment Station, Logan, Utah.
Ball, Wilbur M., Care U. S. Consul-General, Montevideo, Uruguay, S. A.
Barker, Joseph F., Experiment Station, Geneva, N. Y.
Barre, H. W., Clemson College, Clemson, S. C.
Bartlett, Harley Harris, Bu. Plant Indus., Dept. of Agr., Washington, D. C.
Bell, Henry G., Nat'l Fertilizer Assoc., 919 Postal Tel. Bldg., Chicago, Ill.
Bell, James M., University of North Carolina, Chapel Hill, N. C.
Bennett, Hugh H., Bu. Soils, Dept. of Agr., Washington, D. C.
Benzin, Basil M., Imp. Dept. of Agriculture, St. Petersburg, Russia.
Binford, E. E., Agricultural College, College Station, Tex.
Bizzell, James A., Cornell University, Ithaca, N. Y.
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Bonns, W. W., Citrus Experiment Station, Riverside, Calif.
Boss, Andrew, Experiment Station, University Farm, St. Paul, Minn.
Bouyoucos, G. J., Experiment Station, East Lansing, Mich.
Bower, H. J., Experiment Station, Storrs, Conn.
Bowman, Albert E., U. S. Office Farm Management, Laramie, Wyo.
Bracken, John, Saskatoon, Saskatchewan, Canada.
Briggs, Lyman J., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
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Cole, John S., Majestic Bldg., Denver, Colo.
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Montgomery, E. G., College of Agriculture, Ithaca, N. Y.
Mooers, Chas. A., Experiment Station, Knoxville, Tenn.
Moore, R. A., University of Wisconsin, Madison, Wis.
Moorhouse, L. A., Agricultural College, Winnipeg, Manitoba, Canada.
Morgan, G. W., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Morgan, J. O., Experiment Station, College Station, Tex.
Morrison, J. D., Experiment Substation, Highmore, S. Dak.
Morse, Fred. W., Experiment Station, Amherst, Mass.
Morse, W. J., 121 V St., N. W., Washington, D. C.
Mosher, M. L., Care Clinton County Commercial Club, Clinton, Iowa.
Mosier, J. G., Experiment Station, Urbana, Ill.
Musback, Fred L., University of Wisconsin, Madison, Wis.
Myers, C. H., College of Agriculture, Ithaca, N. Y.
Napier, J. M., Clemson Agricultural College, Clemson College, S. C.
Nash, C. W., Experiment Station, Manhattan, Kans.
Nelson, Martin, Experiment Station, Fayetteville, Ark.
Newton, Robert, Agricultural Extension Branch of Macdonald College, Shawville, Canada.
Nichols, Mark L., 67 W. 10th Ave., Columbus, Ohio.

Oakland, Irwin, Experiment Station, Brookings, S. D.
Oakley, R. A., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Olson, George A., Experiment Station, Pullman, Wash.
Orton, W. A., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Packard, Walter E., El Centro, Calif.
Pammel, L. H., Dept. Botany, Experiment Station, Ames, Iowa.
Patten, Harrison E., Bu. Chemistry, U. S. Dept. of Agr., Washington, D. C.
Patterson, H. J., Experiment Station, College Park, Md.
Pettit, J. H., College of Agriculture, Urbana, Ill.
Piper, C. V., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Porter, W. R., Extension Department, Agricultural College, N. Dak.
Potter, Harry B., 9 South Sixth St., Fort Atkinson, Wis.
Quereau, F. C., Rice Experiment Farm, Crowley, La.
Rast, Loy E., State College of Agriculture, Athens, Ga.
Raymond, L. C., Farnham, Province of Quebec, Canada.
Reid, F. R., Bu. Soils, U. S. Dept. of Agr., Washington, D. C.
Robbins, F. E., 217 Waldron St., West Lafayette, Ind.
Robert, J. C., Agricultural College, Miss.
Roberts, Geo., Experiment Station, Lexington, Ky.
Roberts, H. F., Experiment Station, Manhattan, Kans.
Roberts, John M., 345 West Michigan St., Chicago, Ill.
Ross, John F., Experiment Farm, Amarillo, Tex.
Rothgeb, B. E., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Salmon, Cecil, Bellefourche Experiment Farm, Newell, S. Dak.
Schafer, E. G., Dept. Agronomy, Agricultural College, Manhattan, Kans.
Schmitz, Nickolas, Experiment Station, College Park, Md.
Schreiner, Oswald, Bu. Soils, U. S. Dept. of Agr., Washington, D. C.
Schutz, H. H., Southwestern Irrigation, Land and Power Co., Los Lunas, N. M.
Scofield, C. S., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Scudder, H. D., Experiment Station, Corvallis, Ore.
Selvig, C. G., Northwest Experiment Station, Crookston, Minn.
Shantz, H. L., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Shaw, Chas. F., Experiment Station, Berkeley, Calif.
Shepperd, J. H., Experiment Station, Agricultural College, N. Dak.
Sherwin, M. E., College of Agriculture, West Raleigh, N. C.
Shoesmith, V. M., Experiment Station, East Lansing, Mich.
Shutt, Frank T., Experimental Farm, Ottawa, Canada.
Sinha, Satyasaran, 28/1 Sukeas St., Calcutta, India.
Skinner, Joshua J., Bu. Soils, U. S. Dept. of Agr., Washington, D. C.
Slate, W. L., Jr., University of Maine, Orono, Me.
Smith, J. Warren, U. S. Weather Bureau, Columbus, Ohio.
Smith, L. H., College of Agriculture, Urbana, Ill.
Snyder, Harry, 2020 Commonwealth Ave., St. Paul, Minn.
Southwick, Everett F., Tagbilaran, Bahol, P. I.
Spillman, W. J., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D C.
Spragg, F. A., Experiment Station, East Lansing, Mich.
Squires, J. H., Technical Div., Dupont Powder Co., Wilmington, Del.
Stanton, T. R., Hyattsville, Md.
Stevenson, W. H., Experiment Station, Ames, Iowa.
Stewart, Robt., Experiment Station, Logan, Utah.
Stoddart, Chas. W., State College, Pa.

Stone, J. L., Experiment Station, Ithaca, N. Y.
Summerby, R., Macdonald College, Macdonald College, P. Q., Canada.
Taliaferro, W. T. L., Agricultural College, College Park, Md.
Taylor, F. W., Experiment Station, Durham, N. H.
Ten Eyck, A. M., Extension Department, Iowa State College, Ames, Iowa.
Thatcher, R. W., Experiment Station, Pullman, Wash.
Thompson, M. J., University Farm, St. Paul, Minn.
Thorne, Chas. E., Experiment Station, Wooster, Ohio.
Tinsley, J. D., 902 South Second St., Albuquerque, N. M.
Tracy, S. M., Biloxi, Miss.
Turlington, J. E., State College of Agriculture, Athens, Ga.
Umberger, H. J. C., Hymer, Kans.
Veitch, F. P., Bu. Chemistry, U. S. Dept. of Agr., Washington, D. C.
Vinall, Harry N., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Waldron, L. R., Experiment Substation, Dickinson, N. Dak.
Warburton, C. W., Bu. Plant Indus., Dept. of Agr., Washington, D. C.
Warren, G. F., Cornell Experiment Station, Ithaca, N. Y.
Wascher, F. M. W., Experiment Station, Urbana, Ill.
Welton, F. A., Experiment Station, Wooster, Ohio.
Wermelskirchen, Louis, U. S. Cereal Field Station, Amarillo, Tex.
Westgate, J. M., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Wheeler, Clark S., 67 West Tenth Ave., Columbus, Ohio.
Wheeler, H. C., 1018 W. Oregon St., Urbana, Ill.
Wheeler, H. J., Service Bureau, Am. Agrl. Chemical Co., Boston, Mass.
Wheeler, W. A., Dakota Improved Seed Co., Mitchell, S. Dak.
Whiting, Albert L., University of Illinois, Urbana, Ill.
Whitson, A. R., Experiment Station, Madison, Wis.
Wiancko, A. T., Experiment Station, Lafayette, Ind.
Widtsoe, John A., Agricultural College, Logan, Utah.
Williams, Chas. Burgess, Experiment Station, West Raleigh, N. C.
Williams, C. G., Experiment Station, Wooster, Ohio.
Willier, J. G., 1129 Euclid St., N. W., Washington, D. C.
Wilson, Frank T., Clemson College, Clemson, S. C.
Winsor, L. M., Box 427, Alamosa, Colo.
Winters, R. Y., College of Agriculture, Ithaca, N. Y.
Wood, M. W., Boise, Idaho.
Woodard, John, Agricultural Building, Urbana, Ill.
Woods, A. F., Experiment Station, University Farm, St. Paul, Minn.
Woodworth, C. M., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Worsham, W. A., Jr., State College of Agriculture, Athens, Ga.
Worthen, E. L., Experiment Station, State College, Pa.
Wright, Chas. Shannon, Campbell-Soup Farm, Riverton, N. J.
Yoder, P. A., Bu. Chemistry, U. S. Dept. of Agr., Washington, D. C.
Youngblood, Bonney, Experiment Station, College Station, Tex.
Zavitz, C. A., Ontario Agricultural College, Guelph, Ontario.
Zook, L. L., Bu. Plant Indus., U. S. Dept. of Agr., Washington, D. C.

4. PROCEEDINGS.

Most of the data regarding the PROCEEDINGS is presented in the report of the Committee on Publication, where it more properly belongs. Matters relating to the sale of the PROCEEDINGS, however, are not handled by that Committee.

Sale of Proceedings.

On recommendation of the Secretary, the Executive Committee considered the question of reducing the cost of the volumes to recent members wishing to complete their sets. In July, 1912, the Executive Committee authorized the Secretary to sell the three volumes to members at $1.25, $1.00 and $1.50, respectively, a total of $3.75, instead of $5.50 as formerly. The price to libraries and non-members remains as before.

Since this authorization the Secretary has written personal letters, as time permitted, to all joining in 1910 who had not purchased Volume 1; all joining in 1911 who had not purchased Volumes 1 and 2, and to all 1912 members who had not purchased the full series of three volumes. The appeal was made to members to purchase the volumes not only to complete their sets but also from the motive of providing funds with which to found a serial publication. The sending of these letters covered a period of several weeks, the last being sent only recently. The response has been very gratifying and replies are still coming steadily. A few of our older members, however, have declined to purchase, stating that the volumes were readily accessible in libraries. On the other hand, a few of the younger men have regretted their inability to purchase at the present time through the lack of available funds.

Table I shows the total number of new members added since each volume was published, the number who purchased the volume before the reduction in price, the number who have completed their sets since, and the number who have not yet purchased.

Table I.—*Data Showing the Purchase of Volumes of* Proceedings *by Members Joining after Publication of Each Volume.*

Volume Number.	Members Added After Volume was Published.	Members Purchasing			Members Not Yet Purchasing.
		Before Reduction.	After Reduction.	Total.	
1	150	46	29	75	75
2	104	28	16	44	60
3	33	1	13	14	19

Copies of Proceedings on Hand.

The following table shows the edition printed of each volume of Proceedings, the number distributed to members, the number sold last year, the number sold in 1912, and the number of copies remaining on hand November 6, 1912.

Table II.—*Showing Disposal of* Proceedings *and Number of Copies Still in Stock on November 6, 1912*

Data on Disposal.	Copies of					
	Vol. 1.		Vol. 2.		Vol. 3.	
Number printed		501		517		516
Distributed to members	129		168		231	
Sold in 1911	31					
Sold in 1912	94		89		41	
Gift to Congressional Library	1		1		1	
Total number distributed	255	255	258	258	273	273
Copies on hand		246		259		243

Since the reduced rate on the volumes of PROCEEDINGS and the need of funds for serial publication were only recently called to the attention of new members and orders are coming steadily, there is reason to believe that the stock on hand will be considerably reduced in the next few weeks, to the profit of both purchasers and Society.

PUBLICATION OF A JOURNAL.

A year ago I urged consideration of the question of beginning serial publication. I now urge the establishing of such a form of publication by the Society early in the year 1913. While not in as good financial condition to do this next year as it doubtless will be during the following year, still the Society can carry it successfully, in my judgment, and there is no other real reason for delay. Journal publication will probably prove a drawing card in itself and will help build its own supporting membership. By steady and consistent effort enough copies of the volumes of PROCEEDINGS already published can be sold to libraries and members who have not yet purchased them to yield funds sufficient, with those derived from yet unpaid dues for 1912, to cover the cost of volume 4. This will leave the membership dues of 1913 undisturbed to carry the cost of the journal and the running expenses for that year. They should be quite sufficient for the purpose. Let us found a journal![3]

5. MINUTES OF MEETINGS IN 1912.

MINUTES OF THE SPECIAL SUMMER MEETING AT LANSING, MICH., JULY 11, 1912.

First Session.

The meeting was called to order in the Agricultural Building of the Michigan Agricultural College at 1 P.M., by President R. W. Thatcher. In the absence of the Secretary, C. G. Williams was appointed Secretary pro tem.

Frank A. Spragg, of Michigan, gave a paper on "The Effect of Selection in Pure-line Oat Work." The paper was discussed by Jardine, of Kansas, Williams, of Ohio, Thatcher, of Washington, Cutler, of Canada, Wiancko, of Indiana, and Mooers, of Tennessee.

George J. Bouyoucos, of Michigan, gave a brief abstract of a paper by T. A. Lyon and J. A. Bizzell on "The Plant as an Indicator of Relative Density of Soil Solutions."

Papers were given by G. F. Warren, of Cornell University, on (*a*) "The Relation of Fertilizers to the Kind of Crop," (*b*) "The Business Aspect of the Interpretation of Fertilizer Tests." Discussion was made by Director Lipman, of New Jersey, H. G. Bell, of Illinois, and A. T. Wiancko, of Indiana.

The session then adjourned.

Second Session.

The second session of the Association was called to order by President Thatcher at 5 P.M.

[3] By vote of the Society in business session this matter was referred to the Executive Committee with power to act and the Committee subsequently approved beginning journal publication in 1913.—SECRETARY.

A paper was presented by Frank D. Gardner, of Pennsylvania, on "The Use of Lime on Land." Discussion by Director Lipman.

A paper on "Osmosis in Soils" was then given by C. J. Lynde, of Canada. The session then adjourned.

Third Session.

The third session was held at 8 P.M.

A paper by Henry G. Bell, of Illinois, on "The Relation of Agricultural Experiment Stations and Colleges to the Fertilizer Industry" was presented.

Papers on "Soil Laboratory Methods," by A. G. McCall, of Ohio, and on "A Method of Recording the Results of Students' Work in the Soils Laboratory," by L. E. Call, of Kansas, were then given. The last two papers were discussed by Haskell, of Massachusetts, and Jardine, of Kansas.

The meeting then adjourned without date.

C. G. Williams,
Secretary pro tem.

Minutes of the Fifth Annual Meeting, Atlanta, Georgia, November 11–12, 1912.

First Session, Monday Evening, November 11.

The meeting was called to order by President Thatcher at 8 P.M., Monday, November 11, in the assembly room of the Piedmont Hotel. After introductory remarks by the President, the reading of papers was begun.

The first paper, entitled "Care and Management of Land Used for Experiments with Farm Crops," was given by Professor C. A. Zavitz, of the Ontario Agricultural College. This paper was discussed by Professors Roberts, Kilgore, and Christie.

At this point the President appointed Auditing and Nominating Committees, as follows:

Auditing Committee.

Lyman Carrier, *Chairman,* George Roberts.

Nominating Committee.

C. A. Zavitz, *Chairman,* C. E. Thorne, J. G. Lipman.

The reading of papers was then resumed.

The second paper, entitled "Notes on Soy Bean Production," presented by Dr. J. G. Lipman, was discussed by Professors Thorne, Roberts, Kilgore, Carrier, and Fain. This was followed by a paper entitled "Seed the Important Factor in the Control of Cotton Anthracnose," by Professor H. W. Barre, Clemson College, South Carolina. The paper by L. S. Klinck, entitled "The Improvement of Small Grains at Macdonald College, Quebec," was read by the Secretary.

None of the other papers scheduled for this session being present, the session adjourned.

Second Session, Tuesday Morning, November 12.

The session was begun by the reading of a paper entitled "The Relation of Farm Management to Agronomy," by Professor W. J. Spillman, Bureau of Plant Industry, U. S. Department of Agriculture.

A paper entitled "Exchange-of-Soil Experiments upon the Composition of Wheat," by Doctors J. A. LeClerc and P. A. Yoder, of the U. S. Department of Agriculture, presented by Dr. Yoder, followed. This was discussed by Professors Thorne, Lipman, Spillman, Thatcher, and Ball.

The third paper presented was entitled "The Relation of the Length of the Ripening Period to the Composition of Wheat," by Director R. W. Thatcher, of Pullman, Washington. This was discussed by Professors Mooers and Spillman.

The fourth paper, entitled "The Coöperation of the United States Weather Bureau with the Agricultural Colleges and Experiment Stations in the Study of Agricultural Meteorology," by J. Warren Smith, U. S. Weather Bureau, Columbus, Ohio, was then presented.

Third (Business) Session, Tuesday Morning, November 12.

The minutes of the fourth annual meeting were approved without reading as printed in volume 3 of the PROCEEDINGS. The minutes of the special summer meeting held at Lansing, Michigan, containing no business transactions, were also approved without reading.

The report of the Secretary was read by Secretary Ball and accepted. The report of the Treasurer was read by Professor Carrier and accepted. The statement of the Auditing Committee was read by Professor Carrier and approved.

The report of the Nominating Committee was read by Professor Zavitz and accepted. On motion the Secretary was ordered to cast the ballot of the Society for the nominees of the Committee. This being done, the following officers were declared elected:

President, L. A. Clinton, Connecticut.
First Vice-President, L. H. Smith, Illinois.
Second Vice-President, Lyman Carrier, Virginia.
Secretary, Carleton R. Ball, Washington, D. C.
Treasurer, George Roberts, Kentucky.
Program Committee, Alvin Keyser, Ft. Collins, Colorado; F. H. Shutt, Ottawa, Canada.
Representative on Council of Affiliated Societies of Agricultural Science, R. W. Thatcher, Pullman, Washington.

The report of the Executive Committee was presented by Chairman Thatcher and accepted.

The report of the Program Committee was presented by Chairman Miller and accepted. On recommendation of the Program Committee it was recorded by motion as the sense of the Society that only such papers should be given place in the printed program as are to be presented by the author or by some one representing the author.

The report of the Committee on Publication was presented by the Secretary and accepted.

The report of the Committee on Terminology was made verbally by Chairman Ball and accepted.

On motion the Executive Committee was empowered to call special meetings at its discretion.

It was moved that the Executive Committee be instructed to report at the next annual meeting their findings concerning the publication of a journal. On

substitute motion it was ordered that the Executive Committee be empowered to act in the matter of publishing a journal, after careful consideration of the finances of the Society and the cost of such publication.

On motion the matter of listing all PROCEEDINGS with foreign booksellers, at a reduction in price if necessary, was referred to the Executive Committee.

On motion the matter of advertisements in the proposed journal was referred to the Executive Committee with power to act.

On motion the session adjourned.

Fourth Session, Tuesday Evening, November 12.

This session was a joint session with the Society for the Promotion of Agricultural Science for the purpose of hearing the presidential addresses. These were delivered as follows:

"Obstacles to Progress in Agricultural Science," by Dean E. Davenport, President, Society for the Promotion of Agricultural Science.

"The Relation of Research to Demonstration Work in Agriculture," by Director R. W. Thatcher, President, American Society of Agronomy.

The meeting then adjourned without date.

Twenty-five members of the Society were in attendance at the various sessions, with an average attendance at each session of 40 to 50 persons.

6. STANDING COMMITTEES FOR 1913.

During 1912 seven standing committees have represented different lines of activity in the Society. Of these, two, the Executive and Program Committees, were reconstituted for 1913. One, the Committee on Soil Classification and Mapping, is a permanent committee of fifteen members, of whom five are appointed each year to succeed those whose terms expire.

Four others, the Committees on Publication, on Standardization of Field Experiments, on Terminology and on Varietal Nomenclature, were continued without change. The personnel of the seven committees is as follows:

EXECUTIVE COMMITTEE.

President L. A. Clinton,
Vice-President L. H. Smith,
Vice-President Lyman Carrier,
Secretary Carleton R. Ball,
Treasurer George Roberts.

COMMITTEE ON PROGRAM.

Alvin Keyser, *chairman;* F. T. Shutt.

COMMITTEE ON PUBLICATION.

C. V. Piper, *chairman;* T. L. Lyon, C. R. Ball.

COMMITTEE ON SOIL CLASSIFICATION AND MAPPING.

Members, 1911–1913.

William H. Day, E. O. Fippin, G. S. Fraps,
Alvin Keyser, B. W. Kilgore.

Members, 1912–1914.

F. J. Alway, R. H. Loughridge, C. F. Marbut,
C. A. Mooers, J. G. Mosier.

Members, 1913–1915.

G. N. Coffey, *chairman;* F. T. Shutt, C. E. Thorne,
H. J. Wheeler, A. R. Whitson.

COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS.

C. V. Piper, *chairman;* E. G. Montgomery, W. H. Stevenson.

COMMITTEE ON TERMINOLOGY.

Carleton R. Ball, *chairman;* C. G. Hopkins, J. F. Duggar.

COMMITTEE ON VARIETAL NOMENCLATURE.

E. G. Montgomery, *chairman;* A. G. McCall, W. M. Jardine.

REPORT OF THE TREASURER.

COLUMBUS, OHIO, November 7, 1912.

I have the honor to make the following report as Treasurer of this Society for the fiscal year 1912.

RECEIPTS.

From former treasurer, Lyman Carrier (balance)	$355.63	
C. R. Ball	82.00	
C. R. Ball	43.19	
C. R. Ball	90.50	
C. R. Ball	86.50	
C. R. Ball	117.00	
C. R. Ball	102.00	
C. R. Ball	59.25	
C. R. Ball	16.00	
27 membership dues for 1911 at $2.00	54.00	
156 membership dues for 1912 at $2.00	312.00	
4 dues for new members for 1912 at $2.00	8.00	$1,326.07

DISBURSEMENTS.

Judd & Detwiler	$ 8.75	
C. R. Ball	14.23	
Lewis M. Thayer	3.85	
Lewis M. Thayer	3.25	
New Era Publishing Co	44.99	
T. L. Lyon	6.72	
New Era Printing Co	392.52	
L. M. Thayer	22.25	
C. R. Ball	19.94	

C. R. Ball	18.05	
A. G. McCall	10.25	
American Writing Paper Co	35.70	
Washington Electrotype Co	.85	
American Writing Paper Co	30.60	
A. G. McCall	5.90	
Maurice Joyce Engraving Co	62.58	
Washington Electrotype Co	.43	
C. R. Ball	7.75	
C. V. Piper	29.29	
Judd & Detweiler	7.75	
The E. Morrison Paper Co	2.40	
A. G. McCall	.50	
F. D. Farrell	2.00	
L. M. Thayer	11.50	
C. R. Ball	17.23	
New Era Printing Co	559.86	
M. F. Miller	5.25	$1,324.39
Balance in treasury November 7, 1912		$ 1.68

Respectfully submitted,

A. G. McCall,
Treasurer.

Auditors' Statement.

We have examined the above report and accompanying vouchers and found them to be correct.

Lyman Carrier,
George Roberts,
Auditing Committee.

November 12, 1912.

REPORT OF COMMITTEES FOR 1912.

No reports were received from three of the seven standing committees, viz., Committee on Soil Classification and Mapping, Committee on Standardization of Field Experiments, and Committee on Varietal Nomenclature. The reports of the other four committees appear below.

REPORT OF THE EXECUTIVE COMMITTEE.

President Thatcher reported the following activities of the Executive Committee. A meeting was held in Ohio Union at Columbus, Ohio, on November 14, immediately after the close of the annual meeting of 1911. The various activities of the Society were considered and a resolution of thanks to the officers of the Ohio State University and Ohio Union was adopted and afterward published in our Proceedings, 3: 22–23.

A meeting of the committee was held at Lansing, Mich., July 11, 1912, to consider a reduction in price of the early volumes of Proceedings to members joining after they were published. By vote the prices of volumes 1, 2 and 3

were fixed at $1.25, $1.00 and $1.50, respectively, a total of $3.75 instead of $5.50 as formerly.

Later, through correspondence, the place for the annual meeting of 1912 was fixed at Atlanta, Georgia, and the dates as November 11 and 12, just previous to the meeting of the Association of Agricultural Colleges and Experiment Stations.

REPORT OF PROGRAM COMMITTEE.

Chairman Miller of the Program Committee reported that calls for papers were sent to all members previous to both meetings of 1912. These calls resulted in nineteen titles for the special meeting at Lansing, Mich., in July, and fourteen titles for the annual meeting at Atlanta.

The chairman further recommended that, in future, no titles be accepted and printed in the program unless the sender had announced his intention of either being present in person or of sending his paper by some member who would be responsible for its presentation. This action was recommended to avoid disappointment of those who attend a session to hear certain papers which are found to be absent, and also to avoid exploitation of the Society by those who wish their names on the program but do not intend to appear or even prepare their papers.

REPORT OF THE COMMITTEE ON PUBLICATION.

Earlier Publication and Better Quality of Volume 3.

One of the endeavors of this year was to publish and distribute the Proceedings of the year 1911 more promptly than former volumes. Volume 1, for 1908–09, was issued in November, 1910. Volume 2, for 1910, was issued in October, 1911, while volume 3, for 1911, the largest and best of all, was published in May, 1912, thus reducing the time by five months. Fully another month was lost in the endeavor to obtain samples of all-rag paper in connection with the printing estimates submitted by various firms. To end this delay the Secretary bought a supply of all-rag paper and obtained new printing and binding estimates which reduced the price by almost exactly the cost of the paper. In this way the Society was enabled to use paper of high quality without greater expense than for the cheaper paper heretofore used. The three successive volumes show an increasing quality and workmanship, and volume 3 is presented to the Society as a publication in which it may properly take pride.

Contents of Volume 3.

Since this volume is provided with both table of contents and index, little need be said of the character of the papers comprising it. It contains fourteen papers, mostly resulting from the fourth annual meeting at Columbus. The papers by Doctors Harris and Morgan contain, in condensed form, the material presented by them as theses for the degree of doctor of philosophy. These papers, and also that by Professor Burgess, were not presented before the Society, but were accepted for publication under the authority given the Committee at the fourth annual meeting in November, 1911.

Cost of the Proceedings.

Below is given in tabulated form the approximate cost of the printing and binding, illustrations, wrapping and mailing, postage and miscellaneous expenses, including freight, express and telegraph charges in connection with the publishing of each of our three volumes.

Table I.—Cost of Volumes of Proceedings.

	Vol. 1.	Vol. 2.	Vol. 3.
Printing and binding	$1.039	$ .73	$1.08
Illustrations, making and insertion	.015	.125	.17
Wrapping and mailing, labor and material	.02	.025	.03
Postage	.11	.09	.13
Miscellaneous	.016	.01	.01
Total	$1.20	$0.98	$1.42

Material for Volume 4.

The program for the summer meeting at Lansing on July 11, 1912, contained nineteen titles. Nine of the papers were presented at the meeting. Several of these papers are now in hand for publication if desirable, and several others will probably be received before the matter goes to press.

The program of the present meeting contains fourteen titles. These two meetings should give us sufficient material for our forthcoming volume. It may be desirable to use some of them in the first number of a serial publication, if such shall be established early in 1913. If more material is needed no less than four very good papers, representing lines of graduate research, have been offered to the Committee on Publication.

Respectfully submitted,

Carleton R. Ball,
Secretary, Committee on Publication.

REPORT OF COMMITTEE ON TERMINOLOGY.

Chairman Ball reported for this committee that while no definite recommendations had been attempted in the matter of agronomic terms, the cataloging of new debatable terms had been continued, with a definition of the term as used by each author. This catalog will serve as a basis for determining present usage and for future recommendation.

CONSTITUTION AND BY-LAWS.

Name.

Article I. The name of this organization shall be The American Society of Agronomy.

Object.

Article II. The object of the Society shall be the increase and dissemination of knowledge concerning soils and crops and the conditions affecting them.

Charter Members.

Article III. All persons expressing a desire to join the Society and paying the annual dues before July 1, 1908, shall be charter members.

Membership.

Article IV. Membership shall be of three kinds, active, associate and local. Active membership shall be limited to persons who are engaged in teaching agronomy or in scientific investigation in some branch of agronomy. Associate membership shall be composed of other persons interested in the object of the Society. Associate members shall be entitled to all the privileges of the Society except that of voting. Local members shall have no vote in the Society and shall not be entitled to a copy of the printed proceedings without payment of an extra sum of money as provided in Article V of this Constitution.

Active and associate membership may be secured by the endorsement in writing of some active member and upon approval by the President and Secretary and payment of the annual dues.

Members who take up residence outside of North America may retain their membership on the same terms as members living in America.

Local Sections.

Article V. Any three members may, with the approval of the Executive Committee, organize a local section of ten or more persons who, if not already members of the Society, may become active or associate members on application and payment of regular dues for such membership. Local sections may make their own rules for membership, provided that for each member who does not become an active or associate member of the Society the local section shall pay to the Society a fee of fifty cents, which shall make such person a local member of the Society and entitled to purchase its PROCEEDINGS for a sum not to exceed the difference between a local member's fee and the annual dues for active membership, but shall not entitle him to a vote in the Society. Any local section may be dissolved by a majority vote of members present at any regular meeting of the Society.

Officers.

Article VI. The officers shall consist of a President, a First Vice-President, a Second Vice-President, a Secretary, and a Treasurer, which officers shall constitute the Executive Committee.

Duties and Term of Office.

Article VII. The duties of these officers shall be those usually pertaining to their respective offices. Their term of office shall be for one year, or until their successors shall have been elected.

Meetings.

Article VIII. When not determined by vote of the Society, the time and place of meetings shall be decided by the Executive Committee.

Amendments.

Article IX. This constitution may be amended by a two-thirds vote of the members present at any regular meeting, announcement of the proposed amendments having been made at least ten days before such meeting.

The Executive Committee may propose amendments at any time between meetings and the same shall be accepted or rejected by a two-thirds vote of the members who mail their ballots within thirty days after the notice of the proposed amendments was sent to them. Any twenty members may initiate a proposed amendment, which shall then be submitted by the Executive Committee to a vote of the Society.

By-Laws.

1. The annual dues for each active and associate member shall be $2, and for each local member $.50, which shall be paid on or before April 1 of the year for which membership is held.
2. Any member in arrears for dues for more than one year shall thereby forfeit membership, but may be restored to membership without action of the Society upon the payment of such arrears.
3. One meeting of the Society shall be held every year if practicable.
4. A quorum at any meeting shall consist of fifteen members.
5. Money shall be paid by the Treasurer only upon the written order of the Secretary.
6. These by-laws may be amended by a two-thirds vote of the members present at any regular meeting.

SCIENTIFIC SECTION.

THE RELATION OF RESEARCH TO DEMONSTRATION WORK IN AGRICULTURE.

R. W. THATCHER.

Agricultural Experiment Station, Pullman, Washington.

PRESIDENTIAL ADDRESS AT THE FIFTH ANNUAL MEETING, ATLANTA, GEORGIA, NOVEMBER, 1912.

Probably the greatest single problem which confronts the administrative officers of agricultural institutions at the present time is the proper distribution of the funds and efforts of the staff between research and the extension, or demonstration, fields. Most such institutions are supported by funds collected as direct or indirect taxes, and the taxpayer is often insistent in his demands for some tangible re-benefit. The serious economic problems involved in the nation's food supply have led to the organization of a host of congresses, associations, societies, or companies of public, semi-public, or private origin and support, having for their avowed purpose the improvement of agricultural conditions, and demanding of our land grant colleges and departments of agriculture much more than it is possible to give of inspiration, information, and intelligence in methods of general farm practices.

That the need is urgent for getting into actual practice, on a very much larger proportion of the farms of this country than at present, of the best methods now known to agricultural science, and of the new facts which are being so rapidly discovered in this field, is generally recognized. This is reflected in the general character of the programs and preparations for the anniversary celebrations of this week. Fifty years ago, the federal government adopted a plan for encouraging collegiate instruction in agriculture and the mechanic arts. Twenty-five years ago federal assistance for research in agricultural science was provided. There seems to be now a nation-wide consensus of opinion that the time is ripe for rapid development of extension service and demonstration work in this field. But in this, as in all great popular movements, there is danger that the enthusiasms of its friends may cause them to over-emphasize its relative importance or to over-

look fields of activity which are equally important, or even fundamental to permanent improvement in agricultural practice. It becomes the duty of men of science, students and investigators in this field, to keep constantly before the public mind the necessity for each of the several features of research, instruction, and demonstration, with their mutual relationships and interdependencies, and their relative needs and importance.

The situation is complicated by the failure of many who are interested in these matters, either as students of conditions or as persons whose means of livelihood are directly dependent upon agricultural production, to recognize the two-fold nature of the field. Agriculture is, always has been, and doubtless always will be, an art, the practice of which affords a means of earning a living to a larger number of people than any other single vocation. But it is also a science, or field of science, the possibilities and fascinations of which we are only just beginning to realize. The proper development of agriculture requires a correct understanding and appreciation of the relative importance and mutual interdependence of these two phases of the field. Many of the difficulties and misunderstandings which oftentimes arise might be avoided if the practical farmer and the agricultural scientist would each realize the different viewpoint of the other, and maintain the sympathetic attitude which their possibilities for mutual helpfulness warrant and demand. One of the frequent and regrettable incidents in agricultural extension work is the intolerance, or open hostility, which is aroused when a skilled scientist, deeply interested in some fascinating problem, such as the relation of the rate of transpiration to proteid metabolism, or of the appearance of heterozygotism in certain hybrid mice, attempts to present the results of his studies to an audience of farmers, whose chief concern in life is how to secure, from a quarter section of land, in a region of limited rainfall, sufficient food, raiment, and shelter for the families dependent upon them. Such farmers are often slow to realize that the ultimate end of the scientist's researches may mean the possibility of enormous increases in production from their own lands or livestock. Equal lack of understanding, or antagonistic feelings, oftentimes arises when a so-called "practical farmer" voices his distrust or contempt for "book farming" to an audience of scientists engaged in lifelong study of problems leading to increased agricultural production and comfort. Fortunately, however, these antagonisms are beginning to disappear as the workers in the two fields recognize their individual limitations and mutual interests.

As leaders in our field of science and thought, we must recognize

this two-fold nature of the field. Then we must adapt our plans to it. As a science, agriculture offers an unequaled field for research. Is there also a field for research in the art, or practice, of agriculture, or is the problem here only one of demonstration and instruction? The organization of divisions of farm management in our agricultural colleges and in the United States Department of Agriculture indicates a growing conception that there is need for instruction, and probably also for investigations, in farm management and agricultural economics, as distinguished from the problems of actual production of farm crops, livestock, etc., etc., which are commonly thought of as "agricultural science." But whether or not the line of distinction between research and instruction shall coincide at every point with the dividing line between the art and the science of agriculture, efficient administration demands a recognition of the possibilities and relationships of these two fields and of the segregation, but coöperation, of the agencies at work in them.

Coming now to the function of research in agriculture, we are immediately confronted by the need for definition of the term and field. Based upon the conception of the two-fold scope of agriculture just mentioned, there are two general types of investigations which are quite different in their methods and purposes. There is, first, the study of scientific principles and phenomena as such, a seeking after truth, if you please, in this field of applied science, in the same way as is done in the theoretical or pure sciences. This is unquestionably research, to which that term may be as properly applied as in any other field of investigation. Then, there is another series of problems which deal with the application of known or discovered scientific principles to the growing of crops, the production of livestock, the distribution of irrigation water, the protection and drainage of overflowed land, etc., etc. Such projects, while not necessarily requiring the discovery of new principles, can be brought to successful culmination only by the accumulation of a considerable mass of experimental data, the outcome of which is uncertain, and which are, therefore, experimental in character, rather than demonstrational. I have fallen into the habit of designating projects of the first mentioned type as research problems, and those of the second kind as experimental. There can, of course, be no exact dividing line between these two classes of investigational work, and it is a question whether the nomenclature here suggested is sufficiently satisfactory to come into general use. The use of the word "experiment" in connection with the establishment of stations for the investigation of agricultural problems at the land grant colleges probably had back of it some con-

ception as that here indicated, and their development also as research institutions is probably a later conception, made possible by the type of scientists employed in them and necessary because of the intricacies of modern agricultural science. In the title of this address the term research has been used broadly to cover all phases of agricultural investigation, but in the subsequent discussions it will generally be used in its narrower sense and the term "experimental work" applied to such projects as consist wholly of the gathering of data as to the best methods of utilization of scientific knowledge in farm practice.

There are at least three different types of research problems. These should be attacked by different methods, and their financial support should, in my opinion, come from different sources. The distinctions between them can probably be best shown by concrete illustrations.

There is, first, the study of fundamental scientific principles, of unlimited application. For example, the Mendelian principles of heredity in plants and animals, the respiration coefficient as a measure of vital activity, the function of certain elements as plant food, are matters of as much importance and as equally applicable in Maine as in California, in Russia or China as in America. Such problems are of nation-wide, or world-wide import, and ought, in my opinion, to be the chief field of investigations by government departments of agriculture and federally-supported experiment stations.

Then, there is a second series of problems for investigation, the results of which are naturally limited in their applicability to certain states or to districts having similar conditions of soil, climate, etc. The investigations concerning the cotton-boll weevil, for example, have only a limited scientific interest and no general applicability to residents of the northern states, while the clearing and bringing into a state of fertility of lands which originally bore heavy forests of coniferous timber has little of interest or concern to the inhabitants of the prairie states of the Mississippi Valley. Such projects as these ought properly to be supported by state funds, either with or without federal coöperative assistance, depending upon the extent of the area, or interests, which will be affected by their outcome.

Finally, there are the purely local problems, such as the production of a variety of wheat specially adapted to the agricultural conditions and market requirements of a given locality, the discovery of a system of tillage which will best utilize a limited or unseasonal rainfall, the remedying of a local soil deficiency or unproductive condition, etc., etc. The support for such enterprises ought to be local, and approximately co-extensive with the district to be benefited by them. The somewhat common practice of calling upon the United States Depart-

ment of Agriculture to solve such purely local problems (which practice probably arises from the supposed greater ease of securing Congressional appropriations than state or district aid for such investigations) is, it appears to me, pernicious in principle and uneconomical in practice. The interest in, and efficiency of, the expenditure of public funds is, in general, directly proportional to the nearness of the source for and the expenditures of such funds.

I am not unmindful of the fact that the successful solution of any such local problem may add to our store of knowledge facts which may be of state, nation, or world-wide interest and importance, and that the line of division between national, district, and local problems of research can never be exactly drawn; but I think that the purport of this discussion is clear.

The kind of men and preliminary training necessary for the successful solution of a research problem varies with the nature of the problem. It is impossible to conceive that any man, in the course of a single lifetime, can accumulate such a fund of scientific knowledge and sufficient experience in methods of investigation as to be able to attack any one of the many different problems of research in agricultural science with certainty of success. It is, I think, equally obviously impossible for any man to serve efficiently in the triple capacity of research expert, field experimentalist and farm demonstrator in his own particular branch of agricultural science. Rare, indeed, if not impossible, is that combination of exactness of mind and accuracy of observation and deduction necessary for successful research, with the breadth of practical experience necessary to foresee and eliminate all disturbing factors in the gathering of experimental data, and the point of view and personal tact and magnetism necessary to helpful demonstration in actual farm practice of the results of research and experimental study. There must be, therefore, the provision of efficient workers in each field, with such adjustment of the duties and responsibilities of each as will secure the most economical and efficient introduction into general practice among the constituency of the institution of the results of its research work.

On the other hand, this country has not yet generally adopted the plan of endowing, or supporting from public funds, any research except such as has an ultimate practical application. "Truth for truth's sake" does not appeal to the American public mind, at least as it finds expression in appropriation's committee rooms, and legislative halls. The real, and perhaps only, purpose of public support for agricultural research is that it may result in improved agricultural practice, and so brings its return to the body politic in increased taxes or

other improved conditions. Whether this be an ignoble or sordid attitude need not be discussed here. The condition exists and must be taken into account in our administrative plans and systems.

On this account the scientist engaged in agricultural research must be prepared and required to carry his study clear through to its ultimate end, namely, its economic application. A study of the life-history and habits of a pest or disease must not stop until its vulnerable point is discovered and a successful method of attack devised. An investigation of principles of breeding must not be dropped until it shall have been ascertained whether the laws which have been discovered can be utilized in the improvement of local races of plants and animals. Of course, there are some men of brilliant scientific ability who have such a lack or abhorrence of vocational art as to make it impossible for them to conceive or execute a practical outcome of their investigations. The work of such men must necessarily be supplemented by that of skilled experimentalists. But the greater number of men who are employed as experts on the staffs of institutions of agricultural research will desire, and should be permitted, to carry their studies through to their ultimate outcome of economic importance.

The solution of the problem having been reached, the problem no longer exists and certainly the results do not belong to the research worker, to be by him disseminated or made a matter of general agricultural practice. The getting of the new information into actual practice now becomes the task of the demonstrator, or extension man, trained and equipped for this purpose, leaving the research worker free to turn his trained intellect and ability to the solution of some new project of research.

I believe it to be a prostitution of the abilities and possibilities of a trained research scientist to require or permit him to spend his time in actually holding the spray rod, following the plow furrow, or selecting improved seed for the purposes of demonstrating his method to farmers. He may have to give actual demonstrations and instruction to a corps of demonstration workers. If efficient men, they should then be better able to take up the task of getting the research worker's results into practice than he himself would be. Let him establish the principle, show its practical applicability if he can, then turn the information over to the demonstration force to get it into public use.

A word or two as to the proprietary interest of the institution, or the public, in the results obtained by such research, while perhaps out of place in this address, seems justified by our own recent experiences.

A late number of a leading trade journal called attention editorially to the fact that there has recently been issued, in Germany, a patent on a process which was dicovered at our experiment station, as a part of our cereal investigations, and given to the public by one of our chemists by publication in that particular journal. This is the third experience of this kind which we have had in recent years. The results of researches of this kind very frequently have a definite commercial value. This leads to a desire for patented use of them by commercial men or organizations. I have at this moment in my pocket a sample of wheat gluten prepared in dry form in such a way that it still retains all its physical properties and is in excellent condition for future physical, chemical, or physiological investigations and use. Our recent experiences make us hesitate to promulgate the method of preparation until some satisfactory and efficient method of protecting its unpatented use to the public can be found. We believe that the demonstration work following the completion of any project, or portion of an investigation, conducted by an institution supported by public funds, should be for the benefit of the general public and not for private advantage to any person or company.

Finally, what is the relation of research work to demonstration work as such, without regard to the personalities of men engaged in it or the nature of the projects involved? Briefly, research is the primary cause and the fountain source for demonstration work. Without research there is nothing to demonstrate. I am aware that there is a large bulk of demonstration work in agriculture which has its inspiration and draws its material, not from the results of scientific study, but from the practical skill of the best farmers of the community or country. So long as there are such practical farmers, with greater skill and more advanced knowledge than their neighbors, their practices serve admirably as examples for others to follow, and it may perhaps be a wise expenditure of public funds to endeavor to widely copy their methods, as an object lesson and inspiration for others. Indeed, every such skilfully operated private farm does serve this purpose, and its influence may be more widely extended if its message is carried to other neighborhoods by extension lecturers and demonstrators. But "no stream can rise higher than its source," and no system of demonstration can hope to bring the great body of farm practice to a higher level than that now attained by skilful farmers, unless it has a constant source of supply of new material and method to draw upon. The research field offers such a source of supply. Without the work in research, the demonstrator's material will soon grow stale and ineffective. Without the demonstration

work, the results of the research will fail to accomplish their purpose, or be slow of final acceptance. Recognizing this interdependence, it ought to be the constant effort of both research and demonstration men to keep their intercourse free and unhampered by jealousies and personal ambitions.

The difficulties arising from failure to appreciate the mutual interests of scientific investigator and practical farmer were pointed out at the beginning of this address. Unfortunately, this lack of appreciation sometimes extends to the demonstration worker, who stands, in a sense, as the interpreter between the two fields and ought to be a most efficient harmonizing agent. Such an unfortunate condition of affairs usually arises where the demonstration or extension service is under separate administration from the research department, the two sometimes appearing as competitors for financial support and carrying the friction and jealousies thus engendered into their respective fields of effort. Such a condition can not be otherwise than deplorable. It narrows the source of supply for inspiration and material for the demonstration worker down to what he can find already in practice. It limits the audience of the investigator to other scientists. It fosters the contempt of farmers for the so-called "theories" of the scientist.

Where the existing laws make it impossible to combine all the demonstration work under one department, the greatest possible care ought to be exercised by those actually engaged in these lines of work to prevent personal ambitions and jealousies from handicapping the proper progress of both agencies. Individual investigators and demonstration workers are but human men, and are often actuated by the same motives and impulses that prompt competitive effort in the business world. But the fact that we are all working for the same ultimate end, namely, improved agricultural conditions and practices, ought to help to do away with personal differences and difficulties and to fuse us into a united system of harmonious parts, working in unison, and each supplementing, supporting, and reënforcing the work of the other.

In furthering this desirable condition, wise and tactful administration by the executive officers of agricultural institutions will be a mighty help. It is to bespeak such help that I have presented my views of the needs of the situation to this joint audience of the American Society of Agronomy and the Society for the Promotion of Agricultural Science to-night.

THE PLANT AS AN INDICATOR OF THE RELATIVE DENSITY OF SOIL SOLUTIONS.

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College of Agriculture, Cornell University, Ithaca, N. Y.

(Contribution from the Department of Soil Technology.)

Presented at the Lansing Meeting, July, 1912.

In conducting a series of water culture experiments with wheat seedlings it was noticed that in the case of the stronger cultures the weight of dry matter produced in the plants per unit of transpiration increased with the density of the nutrient solution in which the plants were grown. It was decided to ascertain whether this held for different kinds of solutions, and for soil treated in different ways.

Plants were grown in 120 c.c. bottles with perforations in the corks through which the plant passed, the corks being arranged to prevent, so far as possible, the loss of moisture except through the plant. The solutions were changed twice a week, at which times the bottles were weighed to determine loss of moisture. Plants were sprouted in crushed quartz and transferred to the bottles a few days after germination. The seedlings were grown for three to four weeks in the bottles. The stock nutrient solution was made up as follows:

	Grams per Liter.
Calcium nitrate	2.70
Magnesium sulfate	0.60
Potassium phosphate	1.50
Ferric sulfate	0.05
Potassium chloride	0.75
Total	5.60

The average results from several series of water cultures are presented in Table I, and are shown graphically in Fig. 1.

These water cultures were grown at three different times, in fact, in three different years, and although the density of the solutions was not exactly the same in every series they were approximately so, having been made up according to the same formula. Determinations of density were made for each series by evaporating the solution in a platinum dish and weighing the residue. After the first two series had been grown it was decided to try, in addition to the cultures already used, a distilled water culture without any solution, in order to ascertain whether the tendency for the dry matter per unit of transpiration to increase would continue with a still more dilute solution.

TABLE I.—*Transpiration and Dry Matter in Wheat Seedlings Grown in Nutrient Solutions of Different Concentrations but of the Same Relative Composition.*

Nutrient Solution.		Number of Plants.	Total Transpiration.	Total Dry Matter in Plants.	Dry Matter per Kg. Transpiration.	Transpiration on the Basis of Solution *F* taken as 100.	Dry Matter on Basis of Solution *F* taken as 100.	Dry Matter per Unit Transpiration on Basis of Solution *F* taken as 100.
No.	Average Density.							
	p.p.m.		*grams*	*grams*	*grams*			
A	4,525	120	8,430	17.7990	2.11	148	177	119
B	2,268	120	8,730	16.0770	1.84	154	160	104
C	736	120	8,010	13.7190	1.71	141	136	97
D	376	120	7,890	12.9960	1.64	139	129	92
E	189	120	6,720	11.0880	1.65	118	110	93
F	83	120	5,670	10.0530	1.77	100	100	100

The distilled water contained from 4 to 8 p.p.m. solid matter, was made from steam carried about 300 feet, of which over 60 feet was vertical pipe, and was condensed in a tin-lined pipe and kept in a block tin tank. It did not come in contact with copper at any time. The results from the series in which distilled water without any

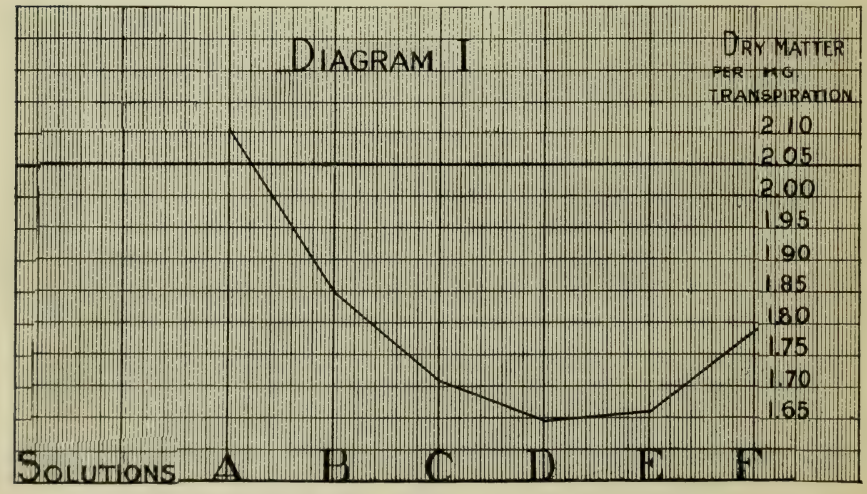

FIG. 1.—Diagram showing dry matter per unit of transpiration in plants grown in water cultures of different densities.

nutrient solution was used as one of the cultures are shown in Table II.

The results agree in showing a decrease in transpiration with a decrease in the density of the nutrient solution in which the plants were grown, except in the case of the most dense solution in Table I,

which was evidently sufficiently concentrated to exert a somewhat injurious effect on the plants. The distilled water produced a very greatly diminished transpiration.

TABLE II.—*Transpiration and Dry Matter in Wheat Seedlings Grown in Nutrient Media Similar to Those Shown in Table I, but Including a Distilled Water Culture.*

Nutrient Solution.		Number of Plants.	Total Transpiration.	Total Dry Matter in Plants.	Dry Matter per 1,000 c.c. Transpiration.	Transpiration on the Basis of Solution *F* taken as 100.	Dry Matter on Basis of Solution *F* taken as 100.	Dry Matter per Unit Transpiration on Basis of Solution *F* taken as 100.
No.	Average Density.							
	p.p.m.		*grams*	*grams*	*grams*			
A	4,444	80	6,800	14.9420	2.29	157	190	124
B	2,222	80	6,420	12.2460	1.96	149	156	106
C	740	80	5,880	10.7100	1.92	136	136	104
D	370	80	5,800	9.9360	1.77	134	127	96
E	185	80	5,360	9.0880	1.76	124	116	95
F	85	80	4.320	7.8460	1.85	100	100	100
G	Distilled water	80	1,840	5.3120	3.06	43	68	165

Dry matter was determined in the crops grown in the various cultures. The dry weight and green weight do not retain the same relation in cultures of different densities, and the former was considered to indicate more accurately the relation that it was desired to bring out in these experiments. The weight of dry matter produced decreased with a decrease in the strength of the nutrient solution.

It may be remarked that the results of the transpirations here recorded do not agree with those reported by Breazeale,[1] who found in growing wheat seedlings for 15 days in solutions having densities of 15, 75, 155, 750 and 1,500 p.p.m. that the maximum transpiration took place at a density of 155 p.p.m. That the next higher density, 750 p.p.m., should injure the growth of wheat plants does not seem possible, unless the nutrient solution was poorly balanced.

The feature of the results that has the most direct bearing on the object of this experiment is the relation of dry matter to transpiration. It will be noticed that the weight of dry matter per unit of transpiration decreases from solution *A* to *D*; that for *D* and *E* the relation is about the same; and that for solutions of less density than *E* the ratio of dry matter to transpiration appears to increase with a decrease in the density of the solution, and is especially high for distilled water.

[1] Science, N. S., 22: 146–149.

Growth of Wheat Seedlings in Nutrient Solutions of Different Densities in Crushed Quartz.

In order to ascertain whether similar relations between dry matter and transpiration obtain when the seedlings are grown in a medium containing solid matter, solutions of the same densities were added to crushed quartz and plants were grown therein. The quartz was placed in wire baskets similar to those used in the Bureau of Soils.[2] The surface of the quartz was in some tests covered with paraffined paper to prevent evaporation, while in other tests a modification of this method was used. This was devised by Dr. George Bouyoucos, at that time a graduate student in this laboratory, and consists in placing glass tubes over the seedlings growing in the quartz and then pouring melted paraffine on the surface of the quartz. The tubes which are sunk into the quartz protect the seedlings and the paraffine makes a close covering over the surface of the quartz. Two sizes of crushed quartz were used. The sizes are known in the trade as Nos. 1 and 2. The particles in No. 1 averaged 160 μ in diameter, and in No. 2 the average was 374 μ.

A larger total number of plants was used in the quartz cultures, there being 100 plants grown in quartz No. 1 and the same number in quartz No. 2. The moisture in the quartz was maintained at 30 per cent. of the dry weight of the quartz. The dry quartz was first brought to this humidity with the nutrient solution of the density to be tested. Distilled water was added twice a week to replace transpired moisture. This insured the quartz solutions not being stronger than the corresponding water cultures at any time and after the first addition of distilled water they were undoubtedly more dilute. The quantity of material in the quartz which passed into solution was, without doubt, small as compared with the densities of most of the solutions. In the distilled water culture the solubility of the quartz doubtless exerted an influence, especially on the dry matter produced per unit of transpiration, and in solution *F* it may have produced a small effect. These quartz cultures were prepared at the same time, planted with seeds germinated at the same time, harvested at the same time and kept under exactly the same conditions as were the water cultures for which transpiration and dry weight are given in Table II. It has, therefore, been considered permissible to compare the results of these two tests. The figures for transpiration and dry matter from the solutions of various densities when used to moisten crushed quartz are given in Table III.

[2] Bulletin No. 23, Bureau of Soils, U. S. Dept. of Agr.

The growth like that in water cultures was best in the strongest solutions. Transpiration and production of dry matter decreased regularly wtih a decrease in density. The relation of dry matter to unit of transpiration is much the same as in the water culture, with one significant exception, namely, that the minimum figure was ob-

TABLE III.—*Transpiration and Dry Matter in Wheat Seedlings Grown in Crushed Quartz Containing Nutrient Solutions of Varying Concentrations.*

Nutrient Solution.		Number of Plants.	Total Transpiration.	Total Dry Matter in Plants.	Dry Matter per 1,000 c.c. Transpiration.	Transpiration on the Basis of Solution *F* taken as 100.	Dry Matter on Basis of Solution *F* taken as 100.	Dry Matter per Unit Transpiration on Basis of Solution *F* taken as 100.
No.	Average Density.							
	p.p.m.		*grams*	*grams*	*grams*			
A	4,444	200	15,200	36.0800	2.37	215	224	104
B	2,222	200	15,040	31.6880	2.11	212	197	93
C	740	200	10,680	22.4120	2.09	151	139	92
D	370	200	9,480	19.6280	2.07	134	122	91
E	185	200	7,880	17.6600	2.24	111	110	99
F	83	200	7,080	16.1080	2.27	100	100	100
G	Distilled water	200	6,160	14.8440	2.41	87	92	106

tained from the solution with a density of 370 p.p.m. where the plants were grown in quartz and in the solution with 185 p.p.m. in the water culture.

Comparing the dry matter produced per unit of transpiration in the quartz and water cultures of the same apparent densities (see Table

TABLE IV.—*Comparison of Dry Matter Per Unit of Transpiration in Wheat Seedlings Grown in Quartz Cultures and Water Cultures at the Same Time and Under the Same Conditions.*

Nutrient Solution.		Dry Matter per Kilogram Transpiration.		
No.	Average Density.	Quartz.	Water.	Difference.
	grams	*grams*	*grams*	*grams*
A	4,444	2.37	2.29	0.08
B	2,222	2.11	1.96	0.15
C	740	2.09	1.92	0.17
D	370	2.07	1.77	0.30
E	185	2.24	1.76	0.48
F	83	2.27	1.85	0.42
G	Distilled water	2.41	3.06	—.65

IV) it will be noticed that the dry matter is uniformly higher for the quartz. Now, as an increase in the ratio of dry matter has, in these solutions, been shown to indicate a greater density of the solution it

is reasonable to believe that the actual densities of the quartz solutions are greater than those of the corresponding water cultures. It has already been remarked that pains were taken to prevent the solubility of the quartz from raising the densities of the solutions used in its cultures. Certain it is that the differences shown in Table IV cannot be accounted for in this way.

It is generally recognized that when a solution comes in contact with a solid body there is a concentration of the solutes in that portion of the liquid immediately surrounding the particles of the solid. In accordance with the phenomenon of adsorption that portion of the solution, therefore, may fairly be supposed to have a density higher than that of the solution before it was added to the quartz.

Wheat seedlings grown in these quartz cultures always possessed abundant root hairs, while those grown in the water cultures did not. The root hairs, as in soil, clung tenaciously to the quartz particles, the surfaces of which were evidently in contact with the absorbing surfaces of the root hairs. It seems quite probable that the absorbing surfaces of the seedlings in the quartz were directly in contact with the much denser solution immediately surrounding the quartz particles and that as a result the absorptive action was determined by a solution of different density than that added to the quartz. This might be termed the effective density of the solution. This hypothesis also affords an explanation for the fact before mentioned, that while the minimum production of dry matter per unit of transpiration was in solution *E* of the water cultures it was in solution *D* of the quartz cultures. It also accounts for the figures shown in the last column of Table IV. It will be seen from this column that the differences in dry matter per unit of transpiration in the quartz and water cultures are greater for the more dilute solutions. As the concentration of solutes due to adsorption is relatively greater for the more dilute solutions this is in accord with the hypothesis outlined.

Growth in Solutions Containing Non-Nutrient Salts.

In order to ascertain what the effect of large quantities of a non-nutrient salt in the solution might have on the production of dry matter per unit of transpiration, wheat seedlings were grown in solutions containing large quantities of sodium sulfate. Solutions were prepared which contained the non-nutrient salt in a different concentration for each solution, but the same strength of nutrient salts in each solution, thus:

Solution.	Concentration.	Sodium Sulfate.	Nutrient Solution.
	p.p.m.	*p.p.m.*	*p.p.m.*
A	5,068	5,000	68
B	2,568	2,500	68
C	901	833	68
D	485	417	68
E	276	208	68
F	150	82	68
G	68	0	68

Wheat seedlings were grown in these solutions in the same way as were those grown in the nutrient solutions of varying densities. The transpiration and production of dry matter are given in Table V.

TABLE V.—*Transpiration and Dry Matter from Wheat Seedlings Grown in Solutions of Non-Nutrient Salts of Different Densities with the Same Quantity of Nutrient Salts in Each Solution.*

Solutions.		Number of Plants.	Total Transpiration.	Total Dry Matter in Plants.	Dry Matter per Kilogram Transpiration.	Transpiration on the Basis of Solution *F* taken as 100.	Dry Matter on Basis of Solution *F* taken as 100.	Dry Matter per Unit Transpiration on Basis of Solution *F* taken as 100.
No.	Concentration.							
	p.p.m.		*grams*	*grams*	*grams*			
A	5,068	40	214.8	.6462	3.01	25	48	189
B	2,568	40	352.9	.8555	2.42	42	64	152
C	901	40	900.2	1.3110	1.45	107	98	91
D	485	40	822.5	1.2240	1.43	98	91	90
E	276	40	782.4	1.2081	1.54	93	90	97
F	150	40	842.3	1.3393	1.59	100	100	100
G	68	40	835.7	1.2153	1.45	99	91	91

It is apparent from this table that, although the total transpiration and production of dry matter are not the same for these solutions as for the purely nutritive solutions, yet the dry matter produced per unit of transpiration maintains practically the same general relation between the solutions of different densities whether they contain non-nutrient salts or not. This method of measuring the density of a solution evidently holds good for mixtures of nutrient and non-nutrient salts such as those used in this experiment. Even those concentrations of the non-nutrient salt which exerted an injurious effect on the growth of the seedlings did not disturb the relation of dry matter to transpiration. The fact that different densities of solutions containing both nutrient and non-nutrient salts are shown by this method, and that the presence of small particles do not interfere with its operation, suggest that it might be used for showing differences in the densities of soil solutions, at least in any one soil under different fertilizer treatments.

Growth of Wheat Seedlings in Fertilized Soils.

While conducting experiments in this laboratory with soils fertilized in different ways, both in the field and in large pots, Dr. J. O. Morgan repeated the tests with wire baskets.[3] Each fertilizer treatment was repeated in thirty baskets with five plants in a basket. The results, therefore, represent the average of 150 plants. The fertilizers used were acid phosphate, muriate of potash and nitrate of soda. They were added separately and in various combinations. The quantities added to the soil in the baskets were calculated from the field applications on the basis of 2,500,000 pounds of soil per acre. A definite moisture content was maintained in each basket throughout

Table VI.—*Effect of Fertilizers Added to Soil on the Production of Dry Weight Per Unit of Transpiration in Wheat Seedlings.*

Group No.	Treatment.	Dry Wt. per Liter Transpiration.	Group 1 taken as 100.
		grams	
1.	No fertilizer	1.188	100
2.	320 lbs. acid phosphate	1.256	106
3.	80 lbs. muriate of potash	1.286	108
4.	160 lbs. nitrate of soda	1.375	116
5.	320 lbs. acid phosphate 160 lbs. nitrate of soda	1.337	113
6.	320 lbs. acid phosphate 80 lbs. muriate of potash	1.315	111
7.	160 lbs. nitrate of soda 80 lbs. muriate of potash	1.459	123
8.	320 lbs. acid phosphate 80 lbs. muriate of potash 160 lbs. nitrate of soda	1.406	118
9.	640 lbs. acid phosphate 80 lbs. muriate of potash 160 lbs. nitrate of soda	1.370	115
10.	640 lbs. acid phosphate 80 lbs. muriate of potash 320 lbs. nitrate of soda	1.406	118
11.	320 lbs. acid phosphate 80 lbs. muriate of potash 320 lbs. nitrate of soda	1.554	131
12.	320 lbs. acid phosphate 80 lbs. muriate of potash 640 lbs. nitrate of soda	1.719	145

the three weeks that the seedlings were grown and the baskets representing each fertilizer treatment were maintained at the same point as those of every other. Transpiration and dry weight were determined for the plants in each basket. From these the dry matter per unit of transpiration has been calculated, and this is shown in Table VI. The fertilizer treatments are designated by the applications per

[3] For description of wire baskets see Circular No. 18, Bureau of Soils, U. S. *Dept. Agr.*

acre in the field. Each fertilizer treatment was applied to thirty baskets or to one hundred and fifty plants.

The production of dry matter per unit of transpiration is in every case greater in the fertilized soil than in the unfertilized one, and in general increases with the quantity of fertilizer added. For large quantities of superphosphate, however, there is a decrease accompanying the heavy application of this fertilizer. Curiously enough, the crops to which these fertilizers were applied in the field were in most cases also decreased in yield by similar applications.

If the conditions that effected an increase in the production of dry matter per unit of transpiration in the water and quartz cultures holds for these soils the conclusion is forced upon us that the addition of fertilizers to this soil increases the effective density of the soil water solution, except in the cases noted above. Quantitatively it is impossible to say what the increase in density would amount to, but it is quite evident that it varies with the different fertilizing materials.

As would naturally be supposed, nitrate of soda has the most marked effect in increasing the apparent density of the solution; muriate of potash is less effective, while acid phosphate is least so. The fact that the soil exhibits less absorptive action towards the nitrate doubtless accounts for its greater effect on the density of the solution.

In thus drawing conclusions from phenomena in which the physiological action of plant roots is concerned, it must be remembered that we can judge only of that portion of the soil solution from which the plant absorbs its mineral nutrients. As this must be confined largely to the root hairs which are in very intimate contact with the soil particles, and which by their secretions possibly add to the solubility of the solid matter with which they come in contact, the effective density as measured by the method above outlined may not be identical with or even proportional to the density of the soil water solution as a whole, but merely that portion of it between the root hair and the soil particle. There may, therefore, be a deposition or adsorption of the fertilizer on the surface of the soil particles in which form it may be included in the effective density of the soil solution, although not in the actual density. The fact remains, however, that so far as the plant is an indicator, the density of the solution with which its absorbing root surfaces come in contact is increased, in the main, by the addition of the kinds and quantities of fertilizers noted above.

Transpiration from Plants Grown to Maturity.

During two years records of transpiration from wheat plants grown to maturity were obtained by Dr. F. S. Harris while working in this laboratory. His figures for transpiration per unit of dry matter

Table VII.—*Dry Matter Produced Per Unit of Transpiration in Wheat Plants Grown to Maturity, 1908–1909.*

(12 Plants in Each Pot.)

Pot No.	Fertilizer.	Soil Moisture Content.	Transpiration.	Dry Matter in Plants.	Dry Matter Produced per Kg. of Water Transpired.	
		per cent.	*grams*	*grams*	*grams*	*Ave.*
43	None	30	25,510	38.16	1.495	1.50
44	None	30	24,390	36.79	1.508	
49	None	15	8,850	15.19	1.716	1.75
50	None	15	7,920	14.09	1.779	
55	Complete	30	31,090	51.35	1.653	1.66
56	Complete	30	30,450	50.67	1.664	
61	Complete	15	11,940	26.63	2.230	2.29
62	Complete	15	10,910	25.69	2.355	
67	High nitrogen	30	35,380	57.26	1.618	1.65
68	High nitrogen	30	32,970	54.86	1.683	
73	High nitrogen	15	10,440	18.80	1.801	1.73
74	High nitrogen	15	11,450	18.98	1.658	

Table VIII.—*Dry Matter Produced Per Unit of Transpiration in Wheat Plants Grown to Maturity, 1909–1910.*

(12 Plants in Each Pot.)

Pot No.	Fertilizer.	Soil Moisture Content.	Transpiration.	Dry Matter in Plants.	Dry Matter Produced per Kg. of Water Transpired.	
		percent	*grams*	*grams*	*grams*	*Ave.*
43	None	30	16,990	18.69	1.10	1.09
44	None	30	16,920	18.43	1.09	
49	None	15	9,820	12.64	1.29	1.33
50	None	15	10,090	13.84	1.37	
55	Complete	30	23,960	32.99	1.38	1.46
56	Complete	30	23,930	36.81	1.54	
61	Complete	15	11,990	19.37	1.62	1.64
62	Complete	15	11,430	18.93	1.66	
67	High nitrogen	30	27,900	45.02	1.61	1.62
68	High nitrogen	30	28,200	46.16	1.64	
73	High nitrogen	15	12,120	20.70	1.71	1.68
74	High nitrogen	15	13,730	22.79	1.66	

produced are given in Tables VII for 1908–9 and VIII for 1909–10, and indicate in general the same relation of this ratio to the fertilized and unfertilized soil as have been shown for seedlings.

Determinations of Soluble Salts with Electrolytic Bridge.

Soil was taken from one of the check plats and to weighed quantities of air-dried soil were added fertilizers corresponding in kind and quantity to the field plat treatments. The applications were made on the basis of 2,500,000 pounds of soil per acre. A given quantity of water was then added to each portion of soil, a sample of which was placed in the cup of the electrolytic bridge[4] and the resistance determined. Readings of these mixtures were made at intervals during ten days. The last readings were used for calculating soluble salts as chlorides.[5]

The effect of the fertilizers was to decrease very greatly the resistance, which indicates a marked increase in the soluble salts in all soils to which the fertilizers were added. A combination of fertilizers produced relatively more soluble matter than the added effect of the same quantities of the two or three constituents added singly.

Table IX shows the increases accompanying the use of the fertilizers used singly and in various combinations on the (1) production of dry matter per unit of transpiration in wheat seedlings grown in wire baskets; (2) the average yields of timothy hay for two years on field plats; (3) soluble salts in the soil water as indicated by the readings of the electrolytic bridge. The soil used in (1) and (3) was taken from one of the check plats used in (2). The applications of fertilizers to (1) and (3) were calculated to 2,500,000 of soil per acre.

Comparing column (1) with column (2), it will be noticed that the relative effect of the fertilizer treatments is the same in nearly every case. For instance, the increases produced by the acid phosphate, muriate of potash and nitrate of soda when used singly are in the same order, as are also the effects produced by the double and triple combinations of these fertilizers. Even where a very large application of acid phosphate has decreased the yield of the hay in the field tests it has decreased the dry matter per unit transpiration in the wheat seedlings.

A failure to correspond occurs in some cases in which the acid phosphate is applied. The effect of this constituent is sometimes to decrease the production of dry matter per unit transpiration and to increase the yield of hay. Column (1) indicates a decrease in the density of the soil solution due to the addition of acid phosphate to nitrate of soda (Groups 4 and 5, also 7 and 8). The same tendency to record a decrease in density is noticeable when the quantities of

[4] Modification of Wheatstone bridge described by Davis and Bryan (Bulletin 61, Bureau of Soils, U. S. Dept. Agr.).

[5] Soil Survey Field Book (1906), p. 37, Bureau of Soils, U. S. Dept. Agr.

this fertilizer are increased. The method is therefore consistent whatever its accuracy may be. The tendency referred to may be noticed by comparing Group 8 with Group 9, in which there is an increase in the addition of acid phosphate accompanied by a decrease in density of solution, while the similarly treated field plats show a corresponding reduction in yield.

TABLE IX.—*Comparison of Effect of Certain Fertilizers on the Yields of Hay on Field Plats and on the Dry Matter Produced Per Unit of Transpiration with Wheat Seedlings Grown in Wire Baskets.*

Group No.	Plat No.	Treatment.	(1) Dry Wt. per Unit Transpiration. Group 1 taken as 100.	(2) Increased Yields of Hay over Check Plats. Check Plats taken as 100.	(3) Sol. Salts as Chlorides Determined by Bridge. Group 1 taken as 100.
1	Checks	No fertilizer	100	100	100
2	712	320 lbs. acid phosphate	106	116	173
3	713	80 lbs. muriate of potash	108	124	166
4	715	160 lbs. nitrate of soda	116	133	178
5	716	320 lbs. acid phosphate 160 lbs. nitrate of soda	113	149	318
6	718	320 lbs. acid phosphate 80 lbs. muriate of potash	111	143	279
7	719	160 lbs. nitrate of soda 80 lbs. muriate of potash	123	166	290
8	721	320 lbs. acid phosphate 80 lbs. muriate of potash 160 lbs. nitrate of soda	118	192	395
9	722	640 lbs. acid phosphate 80 lbs. muriate of potash 160 lbs. nitrate of soda	115	181	479
10	724	640 lbs. acid phosphate 80 lbs. muriate of potash 320 lbs. nitrate of soda	118	240	647
11	725	320 lbs. acid phosphate 80 lbs. muriate of potash 320 lbs. nitrate of soda	131	234	537
12	728	320 lbs. acid phosphate 80 lbs. muriate of potash 640 lbs. nitrate of soda	145	284	1,053

The peculiar response which this soil gave to acid phosphate in field plat tests may be due to a decrease in the effective density of the soil solution when large applications of acid phosphate are made.

A comparison of columns (2) and (3) shows, as did (1) and (2), a fairly consistent increase in soil solution density for the single and combined fertilizers applied, and relative to the increased yield on the corresponding field plats. There are some marked exceptions, one of which may be seen in the single applications of acid phosphate and muriate of potash. According to the reading on the electrolytic bridge, the muriate of potash produced a smaller increase in the den-

sity of the soil solution than did the acid phosphate, while according to the wire baskets the opposite is the case, the latter being in accord with the order of yield. The bridge reading accords better with the yield in the case of the change from a single to a double and a double to a triple fertilizer application, but where a decreased yield is due to an increase in the quantity of acid phosphate applied as on Plats 721 and 722 and Plats 725 and 724, the bridge reading does not correspond with the order of yield on the plats.

There is doubtless an important difference between the solutions, the density of which may be indicated by the wheat seedlings on the one hand and by the electrolytic bridge on the other. The nature of the former has already been discussed, and in the opinion of the writers does not represent the large bulk of the soil water solution, but that portion of it immediately surrounding the soil particles, and possibly not all soluble in the soil water, although soluble in the liquid between the membrane of the root hair and the soil particle.

The solution whose density is indicated by the electrical resistance probably represents the soil water, although the indicated density is undoubtedly modified by the presence of soil particles, the surface effects of which cause the solution to read differently from the same solution in large volume. The readings of solutions, free and in quartz of different sizes at point of saturation in Table X, illustrate this.

TABLE X.—*Comparison of Electrical Resistance of Two Solutions, Free and Saturated with Quartz Particles of Two Different Sizes.*

Solution.	Resistance in Ohms.		
	Free Liquid.	Quartz No. 3½ Coarse.	Quartz No. 1½ Fine.
A	60	150	160
E	1,050	1,900	2,800

There would thus appear to be a higher resistance where the homogeneity of solution is interfered with by the particles of quartz. It is therefore probable that the effective density soil solution is greater than the resistances indicate.

The two methods, while differing in detail, agree in indicating a greater density of the solution in the soil to which fertilizers, single and combined, are added. A relatively greater solubility for the acid phosphate is indicated by the electrical resistance than by the plant method, this being the feature in which they differ most.

It is not contended that the method here described is of general application, as it is possibly sensitive to certain changes in the balance

of the nutrient solution. So far as they so, however, the results indicate an increase in the density of the soil solution when nitrate of soda, muriate of potash and rock superphosphate, either singly or in combination, are added to the soil used in the experiment.

It is recognized that there are numerous difficulties, not yet overcome, which make it impossible to draw positive conclusions from all of the data here presented. Chief among these obstacles are the discrepancies which arise from lack of uniformity in the conditions under which the growing tests are made.

The difficulty in obtaining a satisfactory method of measuring the density of soil solutions, even in a comparative way, is taken to justify the publication of this suggestion that the plant may possibly serve the purpose.

Summary.

In the water cultures used in these experiments for growing wheat seedlings the dry matter produced per unit of transpiration increased with the density of the solution except in the case of very dilute solutions.

Wheat seedlings growing in crushed quartz containing the same nutrient solutions as those used in the water cultures produced the same relative quantities of dry matter per unit of transpiration as did the water cultures.

The quantitative production of dry matter per unit of transpiration was, in each case, greater in the quartz than in the water culture of corresponding strength. This may possibly be accounted for by the adsorptive properties of the quartz particles.

In a series of wire basket tests, in which rock superphosphate, muriate of potash and nitrate of soda were added to the soil in different baskets singly and in various combinations, the crops grown in the fertilizer-treated baskets produced in every case a greater quantity of dry matter per unit of transpiration than did the unfertilized soil, and up to a certain point an increase in the quantities of fertilizers used produced the same result.

Taking the relation of dry matter to transpiration as an indication of the density of the media from which the plant absorbs its mineral nutriment, the addition of fertilizers to the soil used in the experiment increased in every case the density of the solution with which the absorbing root surfaces came in contact, and in most cases the density of the soil solution was augmented by an increase in the quantity of fertilizers applied.

A comparison of the method described, with the electrical resistance method, shows that they agree in indicating a greater density of the nutrient solution in the soil to which fertilizers, single and combined, are added, but that in certain cases, notably when acid phosphate is applied, they are not in entire agreement.

The density of the soil solutions, as measured by the Wheatstone bridge, is probably not the same as the effective density of the solution from which the plant draws its nutriment.

A METHOD OF RECORDING THE RESULTS OF STUDENTS' WORK IN THE SOILS LABORATORY.

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Presented at the Lansing Meeting, July, 1912.

Three factors are of the utmost importance for successful instruction in the soils laboratory: First, individual work must be done by the student; second, the exercise used must be of such a nature that definite and accurate results may be obtained; third, a simple and effective way must be employed of recording the work of the student.

The exercises first outlined for laboratory instruction in soils were practical and good considering the small number of students handled and the condition under which the work was given, but many of these exercises were of such a nature that definite results could not be obtained. When the classes in the laboratory were small in size this was not a serious defect, for while definite results were not obtained, the teacher had an opportunity to instruct each student in the particular lesson taught by the exercise. The instructor knew from individual contact with the student the carefulness with which the work had been performed and whether the student had learned the lesson that the exercise was supposed to teach.

As desirable as an intimate acquaintance is between student and instructor it becomes impossible when the number of students enrolled in the course becomes large. With a large number of students in the laboratory it becomes necessary to plan the exercises, that the student by properly doing his work will obtain definite and accurate results and when duplicate determinations are made the data obtained will be comparable. This is the only way in which the instructor handling a large number of students can possibly know the quality of

work done by the individual student and even this will not enable the teacher to obtain an exact estimate of the student's worth if some good method is not employed of recording the results of the student's work.

It is doubtful if a system of recording the results of students' work in the laboratory could be outlined that would meet the requirements of every teacher or even a majority of teachers, because of their difference in personality and the difference in organization of the work in different institutions. We are using a system at our institution that has proven entirely satisfactory under our conditions and enables us to keep in touch at all times with the work of each student.

We use a separate leaf guide book in the laboratory. The student secures at the beginning of the term the guide book which gives him in outline form instructions as to how to conduct each exercise required by the course. When the student comes to the laboratory and carries out the exercise assigned for that day, the data he secures are recorded in a pocket note-book provided by himself. When the work for the day is completed a copy of the data secured is made by the student upon a 3×5 card index filing card furnished by the instructor. The data are arranged on the card according to an outline form printed on similar cards and posted in the laboratory for easy reference by the student. These index cards contain, besides a place for filing the data secured, a place for recording the number of the exercises, the date and the student's name.

If the laboratory exercise is of such a nature that additional weighings or measurements must be made for several days following the laboratory period, the student is required to turn in an additional index card for each day upon which the weighings or measurements are taken, giving the record for that day. The student after properly filling out his card drops it into a locked box placed in the laboratory for that purpose. Each day the box is opened by the instructor in charge of the laboratory and the cards filed in a filing case in consecutive order behind the student's name. These cards not only serve as a record of the student's work but as a means of taking the class roll.

The report that the student makes upon the index card is only a preliminary report of his laboratory work; this is followed within one week after the laboratory exercise is completed by a final report carefully prepared upon notebook paper the same size as that used in the laboratory guide. This final report contains any drawings, curves, tables of data, or reports of reference readings required in the exercise. Since this report is compiled at the student's room, neat and attractive work can be done. This report is bound in a manila

back cover together with the guide sheets of the exercise and turned in by the student in a locked box for this purpose in the laboratory. These reports are corrected and graded by the instructor and if correct and satisfactory are filed in a letter filing case until the end of the term when they are returned to the student. If the guides are incorrect they are returned by the instructor to the student for correction. By this method a correct laboratory exercise is not placed in the hands of the student during the term, so that there is no opportunity for copying and it is absolutely necessary for the student to work up his own data, for the data in the laboratory report must correspond with the data handed in on the index filing cards. This method has made it possible for us to keep at hand at all times a complete record of the work of each student in the laboratory, has systematized and simplified our methods of recording the laboratory work and has made it very difficult for a dishonest student to obtain much information of value from his fellow students.

THE USE OF ASSIGNED READINGS IN INSTRUCTION IN AGRONOMY.

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Presented by Title at the Lansing Meeting, July, 1912.

All good classroom instruction is based upon a text-book or systematic series of lectures dealing with the subject under consideration. However, neither a text-book nor a series of lectures can deal fully with all the phases and facts concerning any subject of importance. If the student gets extended information on a given topic he must do it through extra reading. The primary object, then, of assigned readings is to extend the student's knowledge of the subject in hand.

Obviously, if the reading is to do the most good, it should be in connection with the assigned work for the next classroom period, or just following the discussion of the topic in class. It is not always easy to do this, especially if a rather complete text-book is used and lessons assigned for recitation from it. The lessons may require so much of the student's time that only a few assigned readings on the more important topics can be expected of him.

The method of making assignments requires some attention. Stu-

dents are usually not familiar with the literature of a subject, nor do they know how to find what literature is available on the subject. A list of references, therefore, should be given to immature students and direction how to find them in the library. Each student should be required to read one or more references wholly or in part according to the length of the reference and the time at the student's disposal. Mature students and upper class men should be able to look up the literature of the subject themselves. In fact, making a list of the books and bulletins dealing with a subject is an excellent exercise of itself. For example, a student may be required to present a list of fifty references dealing with the general subject of soils, or he may be required to list the publications of the various experiment stations on alfalfa culture. If he be further required to look into these references and list only such as report definite, conclusive results, or established methods of culture, the assignment will be of still greater value.

After making an extended reading the student should prepare an abstract and present it to the instructor for inspection and criticism. The abstract should be brief, concise, and carefully written. The instructor should insist that it be neatly written, properly paragraphed, and contain no misspelled words. This requires some extra work on the part of the instructor, but brings results of value to the student and makes the classroom instruction more effective. The abstract should give full title of the book or bulletin abstracted, date of publication, and author. If only certain parts have been abstracted, these should be definitely stated.

Some, or all, of the abstracts should be read and discussed in class. With a fair-sized class it will not be possible to read and discuss all of the abstracts, but a sufficient number to maintain interest should be so treated. If the reading and abstracting have been carefully done, the student will want to retain his abstracts as a part of his notes and he should be encouraged to do so. Some time in the future he may want to refer again to the subject. His abstract will furnish the principal points, and if he wants more details he can refer to the original publication.

The author has used the above methods with his classes in soils and in crops, and with all grades of students, and believes that the results are good and of much help to the student.

A THOROUGH TRAINING FOR SPECIALISTS IN AGRONOMY.

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One of the commonplaces of our day is the assertion that this is distinctly an age of specialization and while there is no denying the advantages which have accrued to human society from such extreme division of labor, it appears to me that we have been too prone, in the attempt to achieve it, to overlook some of the factors concerned in an adequate general training for men and women which bear a vital relation to their welfare.

This statement is as true when applied to our system of training for specialists in soil fertility work as it is in general, and I believe that we should give serious consideration to supplying a more enlightening and broadening training for our teachers and investigators before it is too late to stem the tide of progress which is tending in the opposite direction. To this end I beg to submit for the consideration of my colleagues some statements on the subject which appear pertinent and which are based on observation and actual trial in the college curriculum. I shall speak on the subject from two points of view, viz., first, the value to the soil specialist of a good general education and what it should include; second, the value of a many-sided study of the subject of soils to the specialist in soil fertility, in crop production or both.

As to the first point, it must be said that it is no mere theoretical claim to assert that a thorough grounding in fundamental subjects and in those allied to a student's proposed specialty are of distinct assistance to him. We have many examples among our colleagues in which clear thinking and the ability to correlate the results of several allied branches of investigation as well as the power to give them adequate expression in spoken or written language are the result of keenness of perception, deep insight, and a mastery of language which are inculcated by systematic and comprehensive training. Many of our present-day specialists have expressed themselves as being hampered in solving the broader problems which confront them by a lack of a more comprehensive training than is provided for in our modern methods of higher education. They feel, moreover, a deficiency in their training in the use of language which makes it difficult for them to report the results of their investigations or to deliver lectures in a clear, concise and interesting manner. In addi-

tion to that it would appear to be true that an extremely specialized training tends further to limit a man's vision, to make him incapable of being an inspiring teacher and a broad-minded citizen, thereby losing for him many pleasurable and profitable phases of his work and the work of others.

To avoid the production of narrowly trained investigators and teachers in general, therefore, we must preface specialized instruction by general instruction arranged so as to lay a foundation strong and broad enough to produce alertness of mind, clearness of vision, and a taste for intellectual endeavor besides inculcating those principles upon which the particular specialty in question rests.

For specialists in that branch of agricultural science represented by soils and crops, students should receive thorough training in speaking and writing English, in preliminary mathematics and surveying, in reading fluently French or German or preferably both, in ancient and modern history and economics, in general chemistry including historical, in qualitative and quantitative analysis, and at least one course each in organic and physical chemistry. Besides, one year of lectures and laboratory work in every one of the following sciences, geology, botany, zoology, and bacteriology should be required. In addition to these, students should be urged to elect other courses of general culture given in the university.

A good training in English is essential to the specialist whether he be a teacher or investigator, for in either capacity he should possess the power to speak and write the language clearly and forcefully, in connection with his daily work.

Preliminary mathematics are necessary to make the mind alert and ready to undertake the solution of a problem. Surveying especially is as necessary for the agronomist as any part of his training. Many an agricultural college graduate, working in the field, in California, has deplored the fact that he had received no training in surveying while at college.

A good reading knowledge of French or German, or both, are necessary for both the teacher and the investigator, and especially for the latter. Some of the best work in agronomy is still being done in Germany and France, despite the rapid progress made recently in those fields in this country. It behooves every specialist, therefore, to equip himself with a good reading knowledge of the languages named so that he may be in touch with progress abroad, as well as at home, and so that he may therefrom receive valuable suggestions and assistance in his own work, as many of us unquestionably do to-day.

History, as a part of the specialist's training, should be considered

essential for the culture it imparts as well as for the comparison which it makes possible of the past and the present, allowing us to profit by the experiences of those who have preceded us. Economics has an added value in agricultural work since we are beginning to appreciate the essential nature of careful buying and well-kept accounts to successful farming.

All branches of chemistry are, of course, directly helpful to the soils specialist but especially so are analytical, physical, and general inorganic chemistry. In these he should be especially well trained.

Physics, botany, zoology, geology and bacteriology not only bear an intimate relation to agriculture in general, but include many of the foundation principles upon which we must build our work. A thorough elementary training in these is essential to our field of work and special emphasis must be laid on the importance of physiological botany, bacteriology and geology.

Then, as to the second point regarding a broad and systematic training in all branches of soils work, too much stress cannot be laid on the necessity for giving the student a bird's-eye view of the subject first, and then detailed instruction in different branches of it later. The arrangement of courses in soils which we have adopted at the college of agriculture of the University of California has now been in operation for three years and most gratifying results have been obtained with it. Our plan consists in offering a general lecture course in soils which is required of every student in the college of agriculture, and which, by the way, is the only required agricultural course for all students. This course, which is now given during the first term of the year, three hours a week, and which is intended to be extended to a whole year's course eventually, consists of lectures, monthly reports on reading of assigned topics, bi-weekly oral quizzes, and a monthly written quiz, besides the final examinations. In this course the student gains an idea of the complex nature of soil material, its origin, physical, chemical, and biological character, and of the correlation of these with local soil types. There is no reason why a course of this kind, when extended to a whole year's work, should not be a sufficient guide for the college graduate going into practical farming so far as soil management is concerned, especially if the sources of the best information on the subject are indicated and emphasized. At the same time such a course gives the specialist, who intends to delve more deeply into the subject, a comprehensive idea of the field and precludes the possibility of his adopting a one-sided view of it as his education in the different branches of soils progresses.

After the completion of this general course in soils the future

specialist is given one term's laboratory and field work (6 hours a week) in soil physics, dealing with a study of the structure of soils, and the air, temperature, and water relations in it, besides one hour's quiz work on special assigned readings connected with the subject. The course in soil physics is then followed by one term's work (9 hours a week and one quiz period) in soil chemistry or soil fertility. In this course laboratory and greenhouse work cover the complete analysis of soils, special determinations and tests, and sand and soil culture work, treating of the essential nature of nitrogen, phosphorus, potassium, calcium, and magnesium to legumes and non-legumes. Following this course in soil chemistry, or taken contemporaneously with it, is a course in soil bacteriology (9 hours a week and one quiz period) in which laboratory and greenhouse exercises, dealing with the nature, variety and physiological efficiency of the bacterial flora of soils, as well as their modification through soil treatment, is given.

The course in soil physics is given during the first term of the year and the courses in soil chemistry and soil bacteriology during the second term of the year. In addition to these courses, a seminar course of two hours once a week during the second term is required to be taken by all advanced students in soils, including graduate students. In this course papers reviewing a field of research are prepared and read by various members of the class and discussed in the light of the most recent investigations covering the subject. We aim to urge the future specialist to complete all of this work by the end of his junior year, thus making it possible for him to take the undergraduate research course for which all the courses above described are prerequisites. This may be taken as a thesis course or in addition to thesis work. To these courses should be added courses in plant breeding for the crop expert and plant physiology for the soil expert.

In this connection, I wish to call attention not only to the necessity of giving the soils and crops specialist such a complete training in soils as indicated, but also to the desirability of giving such courses under the direction of the division of soils or of agronomy. The idea of giving a student a course in soil chemistry under the direction of a department of agricultural chemistry, a course in soil physics under the direction of a department of agricultural physics and a course in soil bacteriology under the direction of a department of agricultural bacteriology, all of these departments being independent of each other, is, in my opinion, erroneous. It tends to make a disjointed training and fails of the very object which this paper particularly aims to emphasize, namely, the necessity for the nice correlation of

the various factors concerned in the study of soil fertility problems. All the courses named should be directed by one department of soils or soil fertility in which the whole training may be planned with due regard for the proper dovetailing of the several factors concerned in it.

Based on a good general education, such as outlined above, with the systematic and thorough courses in soils in addition as described, such a training should prove invaluable to the graduate specializing in soils. Even if he should not have an opportunity to pursue graduate studies, he will be equipped to undertake both the planning and execution of original experiments in the laboratory, greenhouse, and field, in a broad and independent way. Or if he choose to teach the subject, will find himself giving voice to many-sided views on soil fertility; ideas based on clear thought, logical conclusions, and the inspiration born of thought on the nicety of the correlation of factors in the blind play of the forces of nature. He will possess imagination, his outlook will be on a broad horizon, and his students will profit by their instruction.

This brief statement as to the writer's opinion of what should constitute a well-rounded training for the specialist in soils and crops is offered to my colleagues for criticism and suggestions. From my own careful observation, and from the experience of some who stand most eminent among us with whom I have discussed this subject, the point of view herein taken is fully justified. Why should we continue to turn out automatons trained in a narrow branch of a narrow field of human endeavor, when we can, by a careful revision of our curricula, turn out men soundly trained generally as well as in their specialty? Why have soil physicists who know nothing about soil fertility, or soil bacteriologists who know nothing about soil physics, when we can just as easily give them a thorough training in all of these branches of soil fertility? Why should we train up specialists who cannot follow the work of their colleagues abroad, whose interest instead of extending to everything that concerns man's welfare are narrowed down to a sphere in which the monotony of work, that must soon become routine, robs one of his initiative, originality and human sympathy? It should be our duty to insure for the student a broad general education and a thorough training in his chosen field.

What is wanted in the scientific work in soils or in crop production is not a man who can solve problems in any one narrow branch of the work, but one who can correlate the results of one branch of study with another and apply his data to the solution of problems of general importance or more deep-seated significance. It is just to assert it seems to me that we are already overburdened with a large number

of men in agricultural science who are merely fitted for a narrow range of tasks whose very narrowness gradually divests them of any spark of originality which at one time they may have possessed and thus disqualifies them for leadership in any wide field of endeavor in agricultural science. These remarks are, in my opinion, peculiarly pertinent in our field of work, as carried out in connection with experiment station duties, for here we are required not merely to add a few isolated morsels to the sum total of human knowledge, but to furnish data which will admit of correlation with other data from allied work and of application to the general problems of soil fertility. How can we expect such data, such correlation, and such application if we do not entrust the work to a man who can look at a subject from several angles, take into account all impinging considerations and bring to bear an original and independent mind on its solution?

I trust the time is not far distant when a college training everywhere for the specialist in our work will be in substance similar to that above briefly described. I feel certain that it will inure to the benefit of its recipients and redound to the lasting credit of its authors.

THE IMPORTANCE OF THE PLACE IN THE ROTATION AT WHICH FERTILIZERS ARE APPLIED.

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Presented at the Lansing Meeting, July, 1912.

Practically all bulletins on fertilizer tests seem to assume that the problem is to determine what treatment is required for the particular soil. The differences in crops are usually ignored. As a result, the same fertilizer is often put on each crop in the rotation when an analysis of the results suggests that it may be better to fertilize each crop differently. Farmers have long since learned to vary not only the amount but the kind of the fertilizer used with each crop.

The present practice with experiment stations is much like trying to find the best food for the animals in a particular barn that may contain horses, hogs and hens, all of the feed to be given to the horses, the hogs and hens to live on the residual effect. It will doubtless be found that the best feed for the horses in this barn will contain grit, oyster shell and a considerable excess of corn, because the results from the barn as a whole will be better when horses are thus fed.

Some of the most valuable fertilizer experiments in the United States are those conducted at the Ohio Experiment Station. From these, the conclusion is reached that, "it is evident, therefore, that the plant, as well as the animal, requires a 'balanced ration' for the perfect utilization of its food. The Strongsville soil, however, is found to be relatively rich in nitrogen and potassium, and while it also shows a larger percentage of phosphorus than the Wooster soil it is to be expected, from the previous treatment of the two soils, that a larger proportion of the available phosphorus has been removed than of the available nitrogen and potassium at Strongsville, while at Wooster there has been a comparatively equivalent removal of all three elements. The result is that the phosphorus applied at Strongsville finds already in the soil a supply of available nitrogen and potassium, whereas at Wooster these elements, as well as phosphorus, must be furnished before the full needs of the plant can be met."

This statement is true so far as total crop is concerned, but from the standpoint of profits, it is misleading. Comparing the results on plots 2, 6, 8 and 11, we have the following :

A five-year rotation was run with corn, oats, wheat and two years of hay, with all fertilizers applied on corn, oats and wheat. Plot 2 received 80 pounds of acid phosphate on corn and oats and 160 pounds on wheat.

Plot 6 received the same acid phosphate with 160 pounds of nitrate of soda on corn and oats and 120 pounds of nitrate of soda and 50 pounds of dried blood on wheat.

Plot 8 received the same treatment as plot 2, with the addition of 80 pounds of muriate of potash on corn and oats and 100 pounds on wheat.

TABLE I.—*Total Value of Increase Crop Above the Cost of Fertilizers for Ten Years. Ohio Experiment Station Bulletin 182, pp. 150–156.*

	Corn.	Oats.	Wheat.	Hay.	Total.
P	$4.72	$3.42	$7 98	$ 3.65	$19.77
NP	2.65	.42	7.93	12.27	23.27
PK	4.55	1.48	5.64	7.55	19.22
NPK	.45	−.61	8.49	15.73	24.06

Plot 11 received the same treatment as plot 6, with the addition of 80 pounds of muriate of potash on corn and oats and 100 pounds on wheat.

Table I gives the total value of the increase above the cost of the fertilizer. Table II shows how these values compare with those

secured by phosphorus alone. It will be seen that nothing but phosphorus has ever paid on corn, oats or wheat. In one case, the increased crop was worth a few cents more than the cost of fertilizer, but not enough to pay. But the residual effect of nitrogen on hay has been sufficient to more than offset the previous losses. The same conclusions are reached whether we take the entire ten years or the

TABLE II.—*Fertilized Crops Grown at the Ohio Experiment Station, Showing Returns from Mixed Fertilizers Compared with Phosphorus Alone.*

	Corn.	Oats.	Wheat.	Hay.	Total.
P alone	$4.72	$3.42	$7.98	$3.65	$19.77
NP above P alone	−2.07	−3.00	− .05	+ 8.62	3.50
PK above P alone	− .17	−1.94	−2.34	+ 3.90	− .55
NPK above P alone	−4.27	−4.03	+ .51	+12.08	4.29

first or second rotation. If the residual effect on hay were due to a mineral fertilizer, it might be claimed that it was best to apply this several years in advance, but no one will claim that it is best to put nitrate of soda on corn and oats because the grass that comes a few years later will pay for it. Why not put it on the grass directly?

The conclusions that the farmer should draw from this work would seem to be to try phosphorus on all crops and add nitrogen and probably potash on wheat and hay. This is very different from recommending a complete fertilizer on corn, oats and wheat, with nothing on hay.

A study of results from the Cornell University Agricultural Experiment Station is shown in Tables III and IV. In Table III, the average of all fertilizer plots is added and the percent of increase in the crop is given.

Timothy has responded to fertilizers much more than any of the other crops. The same fertilizers that gave a 10 percent increase with oats have given an average of 72 percent increase on timothy.

So far as I can discover, no fertilizer or combination of fertilizers applied to corn, oats or wheat has ever paid on these plots at any time since the first tests were made, over thirty years ago. No fertilizer or combination of fertilizers has ever failed to pay on timothy. Apparently, on this soil, it is impossible to fertilize the cereals profitably and impossible to fertilize timothy unprofitably with any rational treatment.

Corn has never been profitably fertilized but corn grown without fertilizer following timothy that had been fertilized has paid well. All the cereals give large increases when manure is applied. The

TABLE III.—*Fertilizer Tests on the Cornell University Farm Showing the Relation of Fertilizers to Crops.*

Crop.	Reference.	Average Yields.		Percent Increase.	Ave. Cost of Fertilizer.	Value of Crops Above Fertilizer Cost.
		Unfertilized.	Fertilized.			
Corn, average 3 yrs.	Bul. 4		Less than unfertilized		$	$
Corn, average 3 yrs.	An. Rpt. 1879–80, p. 128	40.98 bu.	42.18 bu.	3		loss
Corn, 1908	Bul. 273	73.2 (ears)	79.8 (ears)	9		loss
Oats, average 3 yrs.	An. Rpt. 1882–3, p. 11	31.45 bu.	35.98 bu.	14		loss
Oats, 1904, 10 plots	Bul. 232	53.8 bu.	59.3 bu.	10	5.80	loss 3.92
Wheat, average 6 yrs.	An. Rpt. 1882–3, p. 15	24.18 bu.	25.75 bu.	6		loss
Timothy, 1905, 10 plots	Bul. 232	2,160 lbs.	3,881 lbs.	80	5.80	3.32
Timothy, 1906, 10 plots	Bul. 241	3,367 lbs.	5,758 lbs.	71	5.80	6.87
Timothy, 1907, 10 plots	Bul. 261	3,178 lbs.	5,266 lbs.	66	5.80	7.49
Corn, 1908, following timothy, no fertilizer on corn	Bul. 273	30.4 (ears)	47.2 (ears)	55		10.52
Mangels, 1907	Bul. 267	12.64 tons	15.61 tons	23	6.28	1.52
Mangels, 1908	Bul. 267	16.89 tons	19.66 tons	16	6.28	3.22

cereals appear to need organic matter, while timothy can use chemicals to better advantage.

Apparently on this farm, the profitable way to use commercial fertilizers is to apply them on the grain with which grass is seeded in order to benefit the new seeding and to fertilize the timothy with a fertilizer rich in nitrogen. This agrees with the results at Ohio, except that this soil is not deficient in phosphorus.

TABLE IV.—*Fertilizer Trials, Cornell University.*

Plot No.	Fertilizer.	Value of Increase Above Cost of Fertilizer.				Cost, Four Years.	Percent Above Cost of Fertilizer.
		Oats.	Timothy, Three Years.	Corn, No Fertilizer.	Total.		
712	P	$-2.82	$7.34	$2.36	$6.88	$6.40	108
713	K[1]	−4.05	12.15	11.28	19.38	6.40	303
715	N	−2.07	8.90	3.08	9.91	14.40	69
716	PN	−3.09	10.71	5.14	12.76	20.80	61
718	PK	−0.99	8.46	8.27	15.74	12.80	123
719	NK	−1.73	19.94	7.91	26.12	20.80	126
721	NPK	−3.60	25.44	14.90	36.74	27.20	135
722	N_2PK	−5.99	12.52	16.42	22.95	33.60	68
724	$2N_2PK$	−7.92	30.59	15.78	38.45	48.00	80
725	2NPK	−6.90	40.76	20.09	53.95	41.60	130

P = 320 lbs. acid phosphate.
K = 80 lbs. muriate of potash.
N = 160 lbs. nitrate of soda.

I have merely used these instances as illustrations. My thesis is that in all fertilizer tests we should give attention to the crop to be fertilized as well as to the soil. The place in the rotation at which fertilizers should be used must be studied before fertilizer tests will be of the most value to farmers.

SOME BUSINESS QUESTIONS INVOLVED IN THE INTERPRETATION OF FERTILIZER TESTS.

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Presented at the Lansing Meeting, July, 1912.

With the present method of calculating results of fertilizer tests, nearly every experiment station recommends to farmers that they use complete fertilizers. Yet the farmer who pays the bills goes on using

[1] Heavy growth of alsike clover on this plot.

the so-called low grade fertilizers on general farm crops. In passing, let me say that I believe the words "low grade" and "high grade" have been so much misused that they ought to be discarded. Anything that is cheap is contemptuously called low grade. Acid phosphate is not necessarily low grade because it does not cost as much as nitrate of soda.

Let us again take the excellent work of the Ohio Experiment Station for consideration, not because I desire to criticise the work of this station, but because its work is typical of the best. The conclusion of this bulletin is the universal one from similar tests that the farmer ought to use a complete fertilizer because plot 11 shows a larger value of crop above the cost of fertilizer than does plots 2 or 6 (Table I).

Comparing plot 8 with 2, we have an additional cost of $6.50. The additional crops paid this and $0.35 besides. Certainly a farmer will not care to spend $8.50 for a fertilizer in the hope of getting back $8.85 in the fall. The 35 cents has to pay interest, crop insurance, hauling and applying fertilizer, harvesting, storing and marketing the increased crop.

TABLE I.—*Results of Second Rotation at Wooster, Ohio, as Reported in Ohio Experiment Station Bulletin 182, pp. 145 and 159.*

	Cost of Fertilizer.	Value of Increase Above Cost of Fertilizer.
Plot 2 P	$ 2.40	$13.99
Plot 6 NP	14.40	19.29
Plot 8 PK	8.90	14.34
Plot 11 NPK	20.90	19.64

Comparing plot 11 with 2, there is an increased cost of $18.50. The increased crops pay this and leave $5.65 to pay for the extra costs. This must pay interest on $18.50, crop insurance, pay for hauling and applying fertilizer and for harvesting and marketing 10 bushels of corn, 15 bushels of oats, 9 bushels of wheat and 1,785 pounds of hay. I do not think that the farmer will find anyone who is willing to undertake this contract for $5.65.

Comparing plots 2 and 6, we find an increased cost of $12 and an increased return of $5.30. It is probable that this will pay. Certainly plot 6 pays better than 11, for no one would be so foolish as to spend $6.50 for fertilizer in order to get back 35 cents more than he paid.

Without a detailed analysis of the results, we would conclude that under the conditions tested one should use nitrogen and phosphorus.

But the farmer who is short of money will spend all he has for acid phosphate because it gives a phenomenal return. Most farmers who have this type of soil are short of money and most of them use fertilizers that contain little but acid phosphate.

Again, on page 173, the conclusion is reached that "The difference, however, between the increase on Plot 2, receiving phosphorus only, . . . and Plot 20, receiving the complete fertilizer, is more than sufficient to justify the greater expense incurred in the fertilizing of the last named plot."

TABLE II.—*Financial Results of a Rotation Experiment with Potatoes, Wheat and Hay, Comparing Phosphorus Alone with Phosphorus, Potassium and Nitrogen. Ohio Experiment Station Bulletin 182, p. 172.*

	Cost of Fertilizer.	Value of Increase Above Cost of Fertilizer.
Plot 2	$ 2.40	$ 8.86
Plot 20	11.40	12.17

The increased cost is $9. The increased value of the crop is sufficient to cover this and leave $3.31. This $3.31 has to pay interest, crop insurance and pay for hauling and applying the fertilizer and for harvesting and marketing the increased crop of 25 bushel of potatoes, 7 bushels of wheat and 337 pounds of clover hay. It is a question as to whether this will pay. Certainly it will not pay if the farmer has a good way to invest money, as, for instance, in more acid phosphate.

The trouble comes from the wrong use of the words "profit" or "gain." The experiment station worker deducts the cost of the fertilizer from the value of the increased crop and calls his answer "gain" or "profit." All the other costs are ignored or matters may be made worse by adding the false statement that it costs no more to grow a large crop than a small one. Such methods of figuring nearly always result in the advocacy of too intensive methods. The same kind of false figuring permeates nearly all station work. The farmers are told that it costs no more to keep pure-bred stock than to keep scrubs, and are even told that the cow and her care cost no more for a thirty-six pound than for a twelve pound cow.[1]

It is no wonder that the business farmer says that these things are all right when you have the state back of you. The majority of the results labeled profit in agricultural bulletins would be serious losses if all costs were considered. It may be contended that the station cannot consider the other costs. This might pass if the experimenter

[1] New York State Department of Agriculture, Circular 27.

would keep his results to himself, but he is not satisfied until he has shown the farmer how rich he will get if he will only follow this new and wonderful discovery. No bulletin should ever be allowed to leave an experiment station that recommends action on the part of the farmer without having considered the real cost. Practically all fertilizer bulletins and many others need to be re-studied before they are safe reading matter for a farmer. There is too much danger that the farmer may follow the advice given.

Results of Cost Accounts in Fertilizing Timothy.

The following are the results from a set of cost accounts in growing timothy hay on a New York farm. A little over 60 acres were fertilized. The increased crop due to fertilizers was about 60 tons. The table gives a very close approximation to the cost of producing the increased crop of 60 tons.

Table III.—*Real Cost of the Increased Crop Due to Fertilizing Sixty-three Acres of Timothy.*

Cost of Fertilizer.		
8,000 pounds nitrate of soda	$185.00	
2,080 pounds muriate of potash	39.77	
10,354 pounds acid phosphate	47.37	$272.14
Other Costs.		
Freight on fertilizer	26.66	
39½ man hours hauling fertilizer at 21.6 c.	8.53	
58 horse hours hauling fertilizer at 13.2 c.	7.66	
29 man hours mixing fertilizer	6.26	
84½ man hours sowing fertilizer	18.25	
101½ horse hours sowing fertilizer	13.40	
200 man hours hauling in 60 tons hay	43.20	
160 horse hours hauling in 60 tons hay	21.12	
108 man hours pitching hay to baler, etc.	23.33	
Meals for hay pressers	14.40	
Meals for hay pressers' horses	7.30	
118 man hours hauling 60 tons to railroad	25.49	
208 horse hours hauling 60 tons to railroad	27.46	
Use of barn (proportionate share)	95.00	
Fire insurance (proportionate share)	3.00	
Interest on above costs for 7 months at 6 per cent	21.46	$362.52
		$634.66

The labor costs are charged at the average cost on this farm for 1911; not the cash paid the men, but the real cost of labor, which includes wood, milk, use of house, etc. Horse labor is charged at cost, 13.2 c. per horse hour, a very moderate cost for a New York farm.

The time required for baling and hauling hay, barn storage room and fire insurance are directly in proportion to the crop grown. These are charged at the average cost per ton for 1911. The extra time of cutting, tedding and raking the larger crop has not been counted. The time to load and haul to the barn is estimated from the time for the total crop, but is very close to correct. The farm is two miles from the railroad and has some bad hills, but over two tons of baled hay is hauled per load. No hay loader is used, but otherwise work is economized.

In most years the 60 tons of hay from this farm will sell for $900. This allows a profit of $265 from fertilizing. Not a profit of $628 that would be indicated by usual methods of figuring.

With hay at $10 per ton there would be a loss from using fertilizer, yet by the experiment station method of figuring the profit would be over 100 percent.

It will be seen that the fertilizer is much less than half the total cost. The costs may be summarized as follows:

Fixed costs—fertilizer, freight on fertilizer, mixing and applying fertilizer, interest on these—$365.25.

Costs directly proportional to crop—hauling in, storage, fire insurance, baling, hauling to market, interest on these—$269.41 or $4.49 per ton.

We can then determine approximately what increases and prices are necessary for profit on this farm. With an increase of half a ton per acre from the treatment, the fixed costs are $365 and the variable costs $135. The 30 tons of hay would have to bring $16.66 per ton to pay the cost.

In some especially good years this treatment may give an increase of 1½ tons per acre. The fixed costs would then be $365 and the variable cost $404. The cost of the 90 tons of hay would be $8.55 per ton.

We find that the increased crop costs $16.66 per ton if the increase is one half ton, $10.58 per ton if the increase is one ton, and $8.55 if the increase is one and one half tons. Farmers in New York often grow hay by ordinary methods at a cost of $6 per ton.[2] These results may suggest the reason that farmers are so slow to take up the fertilizing of hay. If one can grow more acres by ordinary methods, he may do as well or better than by spending his limited capital for fertilizer. If he cannot buy or rent more land, or if he has plenty of money, he may use fertilizers.

[2] A. L. Thompson, "Thesis on Cost Accounts," deposited in Cornell University Library.

THE USE OF LIME ON LAND.

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Presented at the Lansing Meeting, July, 1912.

The Pennsylvania State College Experiment Station has the longest continuous general fertilizer test in America now nearing the close of its thirty-first year. The one hundred and forty-four plats in this experiment with the present marked differences in crop-producing power not only carry important practical lessons for our farmers but also offer a field for soil research of unusual opportunity.

Needless to say, this field for investigation during recent years has not been neglected. During the past five years laboratory research has been in progress on these plats and the results of such investigations may be found in the annual reports of the Pennsylvania State College of the past five years.

Among the investigations is one on the lime requirements of the plats as related to the soil treatment and the correction of the acidity by two forms of lime. It also includes the growth of clover in relation to the application of lime. In this investigation 720 samples, representing 7,200 soil borings, were taken, on which duplicate lime requirement determinations were made, one on the fresh soil and the other on the same soil after becoming thoroughly air dry. As a result of these determinations, there is no evidence to show that soil acidity is generally or markedly reduced upon thorough drying of the soil; although in case of unusual acidity there is a slight tendency toward such a reduction. A seasonal variation in the lime requirement was discovered but such variation was not definitely related to either crop growth or weather conditions.

Extensive crop tests, using clover as the test crop and applying finely pulverized raw limestone and caustic lime to the soil in equivalent amounts, show the limestone to be equally as prompt and efficient in correcting soil acidity and promoting the growth of clover as the caustic lime.

In the following table is given the total green weight of clover from two pots and for two crops. The results are arranged in the table according to lime requirement. There is also given by means of symbols, explained in the footnotes, the field treatment of each of the plats from which the soil was taken.

TABLE I.—*Weight of Green Clover in Grams. Two Crops from Two Pots. Tier 1. 1910.*

Group 1.—Soil Neutral or Alkaline.

Plat.	No Lime.	2,000 Lbs. Limestone.	Field Treatment.
2	20.75	21.00	N.
3	37.40	35.25	P.
4	10.95	16.25	K.
5	40.95	48.20	N. P.
8	28.80	33.15	Nothing.
11	42.90	48.15	3N. P. K.
12	49.20	47.20	1¼N. Pb. K.
15	34.90	37.10	P. K.
22	38.80	37.80	6M. L.
23	28.00	24.85	L.
34	18.75	18.05	Ls.
35	61.75	56.40	1¼N. Pb. K.
Av.	34.43	35.36	

Group 2.—Soil Requires 0 to 500 Lbs. CaO Per Acre.

Plat.	No Lime.	Ground Limestone.		Slaked Lime Veitch.	Lime Requirement, Lbs.	Field Treatment.
		Veitch.	Veitch + Ton.			
1	3.85	2.80	6.00	2.95	182	Nothing.
6	13.60	11.85	13.20	13.05	20	N. — K.
9	35.80	39.80	48.85	42.65	357	N. P. K.
13	5.05	4.80	3.45	4.20	20	Plaster.
14	5.35	6.05	5.70	5.40	21	Nothing.
16	26.30	20.90	21.20	26.80	297	6M.
25	41.50	43.80	42.10	39.25	338	— P. K.
26	44.40	49.10	52.30	45.65	294	Na. P. K.
27	46.70	46.15	53.25	51.25	109	2Na. P. K.
28	45.40	43.50	45.40	42.05	148	3Na. P. K.
29	39.15	43.40	45.20	38.75	423	— P. K.
33	3.70	3.65	3.50	3.40	151	Plaster.
36	7.15	8.80	10.95	6.50	110	Nothing.
Av.	24.46	24.97	27.01	24.76	190	

Group 3.—Soil Requires 500 to 1,000 Lbs. CaO Per Acre.

Plat.	No Lime.	Ground Limestone.		Slaked Lime Veitch.	Lime Requirement, Lbs.	Field Treatment.
		Veitch.	Veitch + Ton.			
7	17.55	18.80	20.40	19.50	911	— P. K.
10	41.10	42.65	52.10	48.95	938	2N. P. K.
17	32.20	43.35	48.90	45.25	997	N. P. K.
20	17.65	19.40	24.15	20.60	914	10M.
21	43.85	50.95	57.75	47.85	759	3N. P. K.
24	13.90	15.80	15.15	14.80	668	Nothing.
Av.	27.71	31.83	36.41	32.83	848	

Group 4.—Soil Requires 1,000 Lbs. CaO or more Per Acre.

Plat.	No Lime.	Ground Limestone.		Slaked Lime Veitch.	Lime Requirement, Lbs.	Field Treatment.
		Veitch.	Veitch + Ton.			
18	27.00	32.30	35.50	32.35	1,041	8M.
19	40.85	56.95	54.60	41.25	1,234	2N. P. K.
30	50.80	56.50	64.40	58.50	1,081	Ns. P. K.
31	3.85	54.90	74.65	67.30	2,086	2Ns. P. K.
32	2.60	46.30	54.20	40.20	1,535	3Ns. P. K.
Av.	25.02	49.39	56.67	47.92	1,395	

N, 1½N, 2N and 3N = 24, 30, 48 and 72 lbs. nitrogen per acre as dried blood.
Na, 2Na and 3Na = 24, 48 and 72 lbs. nitrogen per acre as nitrate of soda.
Ns, 2Ns and 3Ns = 24, 48 and 72 lbs. nitrogen per acre as sulphate of ammonia.
Pb = 48 lbs. phosphoric acid per acre as ground bone.
P = 48 lbs. phosphoric acid (P_2O_5) per acre as dissolved bone black.
K = 100 potash (K_2O) per acre as muriate of potash.
L = 4,000 lbs. slaked lime per acre.
Ls = 4,000 lbs. finely ground limestone per acre.
M = stable manure, 6, 8 and 10 tons per acre as indicated.

It will be noticed from Table I that Group 1, embracing 12 plats, having the soil neutral or alkaline, gave an average growth of 34.43 grams of green clover from two pots when no lime was applied, and an average green weight of 35.36 grams when 2,000 pounds of ground limestone was applied. In Group 2, embracing 13 plats, having a lime requirement ranging from 0 to 500 pounds per acre, it will be noted that the increase in growth for a ton of ground limestone in excess of requirement is relatively somewhat greater than for the first group, but is a comparatively small increase. Comparing the average effect of ground limestone and slaked lime when applied in amounts indicated by the Veitch method, we find but very little difference and that slight difference is in favor of the ground limestone. In Group 3, embracing 6 plats, having a lime requirement ranging from 500 to 1,000 pounds per acre, the differences resulting from lime are much more marked. In this group, however, the slaked lime has given a slightly greater growth than the ground limestone when applied in an equivalent amount. The last group, embracing 5 plats, having a lime requirement of 1,000 pounds or more per acre, shows a very marked increase in the growth of clover following any of the applications of lime. In case of 2,000 pounds of ground limestone in excess of the amount indicated by the Veitch method, the growth of clover is considerably more than double, while it is nearly doubled for each of the other treatments. In this group the ground limestone has again given a greater average growth than the slaked lime, thus

indicating that it has been no less prompt and effective in promoting the growth of clover in these pots than an equivalent amount of slaked lime. A careful study of the results of the first and second crops of clover shows that in case of the first crop, the difference in favor of the ground limestone was more marked than in case of the second crop, or the average of the two crops. The results indicate, therefore, that the slaked or caustic lime when first applied may have slightly retarded the early growth of the clover as a result of its caustic action. The limestone is, of course, neutral in reaction and would have no such effect. Furthermore, it is easily attacked by even the weakest acids, and wherever the soil is acid in reaction the finely ground limestone, when thoroughly mixed with it, is doubtless quite as effective in neutralizing the acidity as the caustic lime would be. In Table I the lime requirement, as determined on June 20, is also given, the requirement being stated as pounds of calcium oxide per acre-7-inches of soil.

TABLE II.—*Lime Requirement as Related to Field Treatment and Increase in Growth of Clover Following Applications of Ground Limestone to Pots at Rate of One Ton in Excess of Requirements.*

No. of Plats.	Field Treatment.	Lime Req'd per Acre as CaO.	Wt. Green Clover.		Increase or Decrease Percent.
			No Lime.	Limestone.	
1	Lime	00	28.00	24.85	−11
1	P	00	37.40	35.25	− 6
2	N, Pb, K	00	55.43	52.80	− 5
1	Limestone	00	18.75	18.05	− 4
1	Manure and lime	00	38.80	37.80	− 3
1	N	00	20.75	21.90	6
1	N, P	00	40.95	48.20	18
1	— — K	00	10.95	16.25	48
1	N, — K	20	13.60	13.20	− 3
2	Plaster	85	4.37	3.48	−20
3	Na, P, K	184	45.50	50.32	11
5	Nothing	196	11.81	14.28	21
4	— P, K	210	33.27	36.20	9
6	N, P, K	714	39.45	51.72	31
3	Manure	751	23.65	26.95	14
3	Ns, P, K	1,567	19.08	64.42	238

In Table II the lime requirement, as related to the field treatment and increase in growth of clover following the application of ground limestone to the pots, is given.

LIME REQUIREMENT AND GROWTH OF CLOVER AS RELATED TO FIELD TREATMENT.

In Table II the pots from all plats given the same character of fertilizer in the field have been brought together and averaged, the

averages embracing both the average lime requirement as determined by the Veitch method on June 20, and the average green weight of two crops of clover on the pots. The weight of clover, however, is reported only for the unlimed soil and the soil receiving ground limestone at the rate of 2,000 pounds per acre in excess of the requirement as shown by the Veitch determination.

It will be noted that where lime, limestone, and manure and lime, as well as phosphate in the form of ground bone, were applied, the soil is not only neutral or alkaline in reaction, but the average growth of clover in all of these cases was reduced in yield from 3 to 11 percent by the application of additional ground limestone. There are two instances where the soil was neutral or alkaline in which there has been a marked increase in growth following the application of ground limestone. These instances are in case of one plat to which potash alone was applied, giving an increase of 48 percent, and the other plat to which dried blood and dissolved bone black were applied, giving an increase of 18 percent. While the average of two plats receiving land plaster showed a low lime requirement of 85 pounds, there was a marked reduction of yield averaging twenty percent following the application of the limestone. Three plats receiving a complete fertilizer, with nitrogen as nitrate of soda, shows an average lime requirement of 184 pounds per acre as compared with an average of 714 pounds per acre for 6 plats receiving a complete fertilizer in which nitrogen was applied as dried blood, the potash and phosphoric acid being the same in form and amount as for the first mentioned three plats. The increase in growth resulting from the lime was 11 percent, where the sodium nitrate was used and 31 percent where dried blood was used. It should be noted, however, that the clover on the untreated pots gave a considerably lower yield for the dried blood than it did for sodium nitrate, while the addition of the limestone brings the average yield in case of dried blood slightly above that obtained by the lime in the presence of sodium nitrate.

The most striking point in this table is the very high lime requirement of the three plats receiving ammonium sulphate and very small growth of clover in the absence of lime, with by far the largest average growth when the acidity is corrected by the use of ground limestone. The increase in growth resulting from limestone, as shown in the table, is 238 percent. This table also indicates that ground bone tends less to bring about an acid condition of the soil than does the same amount of phosphorus in the form of dissolved bone black.

Table III summarizes the results set forth in Table I and gives the relative growth by groups according to range in lime requirement on the basis of 100 where no lime is applied.

TABLE III.—*Relative Growth of Clover as Influenced by Lime; Based on Total Growth from Two Pots and Averaged for the Number of Plats Indicated.*

Number of Plats.	Av. Lime Required, Lbs.	Relative Green Weight of Clover.			
		No Lime.	Slaked Lime Veitch.	Limestone Veitch.	Limestone Veitch + Ton.
12	None	100	—	—	103
13	190	100	101	102	110
6	843	100	118	115	131
5	1395	100	192	197	222

Table III shows an increase in growth for the first group of only 3 percent resulting from the application of ground limestone at the rate of one ton per acre in excess of the Veitch requirement, with 10 percent increase for the second group, 31 percent increase for the third, and 122 percent increase for the last. It will also be noted that in two out of three instances the limestone has given a larger increase than the slaked lime, with but little difference, however, in the averages.

A study of the tables will show a wide range in the yield of clover on pots from the different plats. The average yield from the pots receiving 2,000 pounds of limestone in excess of the lime requirement indicated by the Veitch method on 18 plats making the most satisfactory growth is equivalent to 48,000 pounds of green clover per acre-foot of soil. This is based on 3,500,000 pounds as the weight of an acre-foot. This shows a draft upon the soil by the clover crop in a period of 8 months that far exceeds that which occurs under field conditions. In what measure this very heavy growth and draft upon the soil has increased the acidity of the soil and to what extent it is responsible for the present acid condition of the soil in most pots that were treated with lime in amounts just sufficient to neutralize the acidity is impossible to state.

When the pot experiments were terminated the soil was removed from the pots and the roots of the clover carefully separated from the soil by passing through a sieve. The roots were washed, dried and weighed and the results show a growth associated with lime treatment which closely corresponds to the growth of the tops reported in Table III. Where the lime requirement was greatest, the increase in root growth was somewhat more marked than that of the tops. The dry weight of roots equaled 41 percent of the dry weight of the roots and tops combined. For one half of the plats, giving the largest growth when limed, the absolute amount of dry matter in the roots was at the rate of 8,575 pounds of dry matter per acre-foot of soil.

After growing two cuttings of clover and separating the roots of the same from the soil, the lime requirement was again determined in the same manner as at first. In nearly all of the pots to which lime had been applied in amounts just sufficient to meet the requirements as indicated by the first determination, the soil was found to still be somewhat acid in reaction. Where caustic lime was used, the original acidity had been reduced 71 percent and in case of the ground limestone it was reduced 72 percent. From these results, it is evident that the lime requirement indicated by the Veitch method falls about one third short of the actual amount of lime advisable to apply under field conditions.

Summary.

Pot tests made with clover on soil from each of the 36 plats of Tier 1 showed a range in growth of clover from 2.60 grams on a very sour plat to 61.75 grams on a good sweet one.

Of the 36 plats, 12 were found neutral or alkaline in reaction, and 24 showed varying degrees of sourness. The sourest plat required 2,086 pounds of CaO per acre-7-inches to neutralize the acidity as shown by the Veitch method. This amount, when applied, left a further requirement of 485 pounds at close of pot test. Pots from this plat without lime produced 3.85 grams green clover, and when limed at the rate of 2,000 pounds of limestone in excess of requirement produced 74.65 grams.

The growth of clover on the unlimed pots correlates well with the yields of hay removed from the plats at the present date.

The second crop from the pots was slightly better than the first. The total of the two crops was a great draft on the soil and for 16 plats giving best results was equal to 48,000 pounds of green clover to the acre-foot of soil.

Soil from limed plats showed a reduction in growth of clover when more lime was applied.

Plats with a low lime requirement gave only a small increase in growth when lime was applied.

A marked increase in growth resulted from lime on all plats that were decidedly acid. The greater the sourness, the larger the response to lime.

Clover is not depressed by sourness, requiring 500 pounds or less of CaO per acre. Above this amount, the depression increases with the sourness and growth practically ceases when the lime requirement reaches 1,500 pounds of CaO per acre-7-inches.

Soil of plats to which land plaster was applied was slightly acid, but the additional lime further depressed growth of clover.

The nitrate of soda plats were less sour than those receiving nitrogen as dried blood. Plats receiving manure were equally as sour as those having dried blood.

The sourest plats were those receiving nitrogen as sulphate of ammonia. When the soil from these plats was made sweet with lime or limestone, it produced clover exceeding in amount that from any other plats.

Plats receiving phosphorus as ground bone were less sour than those receiving equivalent amounts of dissolved bone black.

Lime influenced the root growth in the same manner and to somewhat greater degree than the tops.

The root growth was equal to 41 percent of the growth of the tops and roots combined. For 18 plats giving best results with limestone, the root growth in the pots was equal to 8,575 pounds of dry matter per acre-foot of soil.

Of 48 soil samples treated with slaked lime and limestone in amounts sufficient to meet the lime requirement as indicated by the Veitch determination, only seven were satisfied when reëxamined at the close of the pot test. Five of these were satisfied by virtue of probable error in the original determination.

When a ton of limestone in excess of requirement was applied, only three remained acid at the close of the test. One of these was evidently contaminated, and the other two were only slightly acid.

Slaked lime applied in amounts indicated by the method reduced the average requirement by 71 percent as based on the average amount applied. On the same basis limestone reduced the requirement by 72 percent. This indicates that the amount indicated by the method should be increased by about 50 percent in order to meet the real soil requirement.

An important fact in this extensive test is that finely ground limestone has been fully as prompt and effective in reducing soil acidity and promoting the growth of clover as equivalent amounts of slaked or caustic lime.

TILLERING AS A FACTOR IN DETERMINING THE DESIRABLE QUALITIES OF WINTER WHEATS.

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It is a matter of common observation that the wheat plant, if given space and a good soil, will produce a number of culms or stalks from each seed. Whether or not this habit of the wheat plant is an index to other desirable qualities, is a question not fully settled. The data gathered in our work at the Delaware Station seem to indicate that tillering may be looked upon as an expression of certain characteristics of the plant which are associated or correlated with desirable qualities. The wheat plant responds to favorable environment by increasing the number of culms rather than by lengthening the culm or spike or by increasing the number of grains in the spike. That is, the individual plant, if given the opportunity of development, will throw its energies more largely towards increasing the number of culms than to the corresponding increase in size of other parts. For example, the number of culms may be increased from 2 or 3 per plant to 8 or 12, while the length of culm or length of spike would be increased by only a fraction of their length over the corresponding measurements of the plant with the fewer tillers. Thus it would appear that the qualities of resistance and of response to various soil conditions are more clearly expressed by the tendency of a variety to tiller than by the changes in the other physical characters of the plant. The capacity of a variety to do well under varying conditions, is undoubtedly a desirable characteristic. If one variety of wheat will produce better than others on a poor soil or during an unfavorable season, the fact is of value to the grower.

In order to study the habit of tillering in wheats, it is necessary to sow the grain in such a manner that an examination of the individual plant may be made. As ordinarily sown with the drill under field conditions, the plants are so crowded that it is impossible to determine the exact number of culms from each seed. Furthermore, since varieties of wheat differ so widely in the size of kernels, it is quite impossible to get the same number of plants of each variety on a given area. To get a good idea of the behavior of a variety, it is obvious that an intimate study must be made of the individual plants or units of which it is composed. For this reason we have supplemented our wheat variety tests under ordinary field conditions by growing the

varieties in such a manner as to facilitate the study of the individual plant. The varieties of wheat were planted in hills, 6 by 6 inches apart, 130 plants to a variety. This spacing gave the plant ample room for tillering and at the same time permitted the counting of the culms. Two kernels were planted in each hill. When the seedlings appeared they were thinned to one plant per hill. At harvest time each plant was cut separately, the number of culms counted and recorded in a note-book. By this means, the behavior of the entire plant population of a variety with respect to tillering was observed. From these data the *mode* as well as the *mean* of tillering of the varieties could be determined.

TABLE I.—*The Mean Number of Culms in Twenty-one Varieties of Wheat Grown under Various Fertilizer Treatments During the Years 1909–1912, Inclusive.*

Variety.	Bearded or Smooth.	Color of Chaff.	Average Number of Culms Produced.						Average for All Conditions.
			1909.	1910.		1911.		1912.	
			Normal Fertilizer.	Light Fertilizer.	Heavy Fertilizer.	Light Fertilizer.	Heavy Fertilizer.	Late Sowing.	
American Bronze	S	W	5.15	4.86	7.32	4.77	7.60	2.91	5.44
Australian Red	B	W	6.17	5.56	7.13	6.01	8.44	3.63	6.16
Clawson Longberry	S	R	5.00	4.84	6.75	6.46	7.21	3.86	5.69
Dawson's Golden Chaff	S	R	7.44	6.80	7.82	6.57	8.78	3.57	6.83
Early Red Chief	S	R	3.85	4.26	6.64	6.47	8.04	3.29	5.43
Economy	B	R	7.55	6.87	9.53	7.20	9.88	3.85	7.48
Extra Early Windsor	S	R	5.61	5.32	7.18	5.59	7.81	3.63	5.86
Farmers' Friend	B	R	6.91	7.15	7.80	8.32	10.36	4.87	7.57
Fultz	S	W	5.61	6.34	8.12	5.48	7.62	3.42	6.10
Gypsy	B	W	6.81	6.72	8.50	7.21	9.15	4.01	7.07
Harvest Queen	S	W	4.60	4.81	5.43	6.00	6.82	3.24	5.15
Invincible	S	W	4.74	4.13	6.24	4.04	7.28	2.78	4.87
Jones' Longberry No. 1	B	R	4.02	4.23	5.83	6.06	8.50	3.14	5.30
Lancaster	B	R	7.27	6.70	9.93	7.61	8.19	4.71	7.40
Mediterranean	B	R	7.95	6.72	8.90	6.86	9.39	4.44	7.38
Nigger	B	W	6.59	6.15	8.71	6.29	9.57	4.33	6.94
Perfection	S	R	7.82	6.84	7.40	6.42	11.10	4.25	7.30
Red Wave	S	R	5.13	5.05	5.45	3.39	7.10	2.94	4.84
Red Wonder	B	R	6.19	6.73	7.61	5.58	8.58	4.02	6.45
Rudy	B	W	7.11	6.47	8.03	6.98	8.58	4.26	6.91
Swamp	B	R	6.62	6.23	8.29	6.89	8.73	4.03	6.80

That there is a considerable difference in varieties of wheat with respect to their tillering habit is shown in Table I. It should be noted that these are pure varieties so far as recognized by stations and wheat breeders, but not *pure* lines of wheat. These varieties have been grown for four years. During two years, 1910 and 1911, they were grown under two conditions of fertilization. In 1912 the crop was sown very late and without fertilizer. A study of the table will show

that certain varieties are very low in tillering when sown under ordinary or light fertilization. For example, the varieties, American Bronze, Early Red Chief and Harvest Queen have a low average number of tillers per plant. Other varieties, as Lancaster, Rudy and Swamp, retain a relatively high tillering mean under all conditions. This would indicate that certain varieties are much better adapted to poor soil. The average number of culms per plant of the different varieties during the four years varies from 4.84 to 7.57, a difference of 56 percent. Under light fertilization in 1910 there is a range from 4.13 culms per plant of the Invincible variety to 7.15 culms in the Farmers' Friend variety, a difference of 73 percent. Where the varieties have been grown under heavy fertilization, the range of tillering between varieties is not so great. In 1911, where fertilized heavily, the variety Farmers' Friend averaged 10.36 culms per plant, while Invincible, under the same conditions, averaged 7.28 culms, a difference of 42 percent. The relation of tillering to variety holds the same between varieties in the year 1912 when the varieties were sown late and under unfavorable conditions. Red Wave and Invincible are among the lowest for that year, while Farmers' Friend and Lancaster are the highest. These figures indicate that varieties differ in tillering less widely under favorable conditions of soil and season.

In order to more fully determine the extent to which varieties would tiller, a number of varieties were planted on soil which was fertilized as follows: Plat 1 received no treatment; plat 2, fertilizers sufficient to produce 25 bushels of wheat; plat 3, fertilizers for 50 bushels; plat 4, fertilizers for 75 bushels; plat 5, fertilizers for 100 bushels of grain. No account was taken of the available fertility of the soil. Each variety consisted of 260 plants 6 by 6 inches apart. The average number of culms per variety under each treatment is seen in Table II.

TABLE II.—*Tillering of Varieties of Wheat under Different Degrees of Fertilization in a Single Season.*

Variety.	Bearded or Smooth.	Color of Glumes.	Average Number of Culms per Plant when Sufficient Fertilizers Were Applied for the Following Yields of Wheat per Acre.				
			None.	25 Bu.	50 Bu.	75 Bu.	100 Bu.
Dawson's Golden Chaff	S	R	5.87	7.66	8.31	9.52	11.71
Early Ripe	S	R	4.56	7.49	7.66	10.05	10.36
Farmer's Friend	B	R	5.92	9.44	11.33	11.13	14.24
Fultz	S	W	4.93	6.88	7.12	8.07	9.74
Gold Coin	S	R	5.34	7.51	8.60	8.46	13.69
Gypsy	B	W	5.07	8.17	8.89	11.11	11.10
Lehigh	B	R	7.24	9.40	10.54	11.64	13.55
Mealy	S	W	5.52	7.34	8.12	8.81	11.08
Velvet Chaff	B	W	4.44	7.35	7.65	9.21	10.81

Here again appears great elasticity on the part of varieties with respect to tillering. Those varieties which tiller best under no fertilization generally develop a larger number of tillers when well fertilized. However, the greatest range in tillering is shown on the unfertilized plats. The Lehigh variety made an average of 7.24 culms per plant, while Velvet Chaff made 4.44 culms, a difference of 63 percent. The same varieties, under the heaviest fertilization, gave a difference of 25 percent.

If with the increase in the number of tillers per plant, the yield per plant is not increased, the habit of tillering is not necessarily indicative of a more productive variety. Table III gives some idea of the relation of tillering to yield.

TABLE III.—*Relation of Tillering to Yield Per Plant and Per Spike in Wheat.*

Variety.	Fertilizer Applied per Acre.	No. of Plants.	Total Yield of Grain.	Difference in Yield.	No. of Culms per Plant.	Difference in Number of Culms.	Yield per Plant.	Difference in Yield per Plant.	Yield per Spike.
	Lbs.		*Grams.*	*Grams.*			*Grams.*	*Grams.*	*Grams.*
Fultz.....	none	666	1,496		4.46		2.24		.50
Lehigh.....	none	656	1,797	301	5.54	1.08	3.01	.77	.54
Fultz.....	200	710	2,252		5.63		3.17		.56
Lehigh.....	200	699	2,663	411	6.69	1.06	3.80	.63	.56
Fultz.....	400	718	2,640		6.71		3.67		.54
Lehigh.....	400	750	3,716	1,076	7.64	.93	4.95	1.28	.64

It will be noted that the Lehigh, a bearded variety, is decidedly superior to Fultz, a smooth variety, in every degree of fertilization (Fig. 2). Not only does the Lehigh yield more per plant, but the yield per spike is also greater. Also the yield per spike increases as the number of tillers per plant increases.

This experiment further shows that as large a yield was secured with Lehigh fertilized with 200 pounds as with Fultz with 400 pounds of fertilizer.

That the tendency to tiller is indicative not only of greater vigor and capacity for development under unfavorable conditions but also of greater yield of better quality per spike is shown in Table IV. Ten plants of two tillers each, ten of three tillers each, etc., up to ten plants of ten tillers each were selected from two varieties which were grown under the same conditions of fertilization. The average length of culm and of spike are shown for each set of plants, together with the yield and quality of grain produced.

It will be noted that as the number of tillers per plant increases, the length of culm increases but slightly, as does also the length of spike.

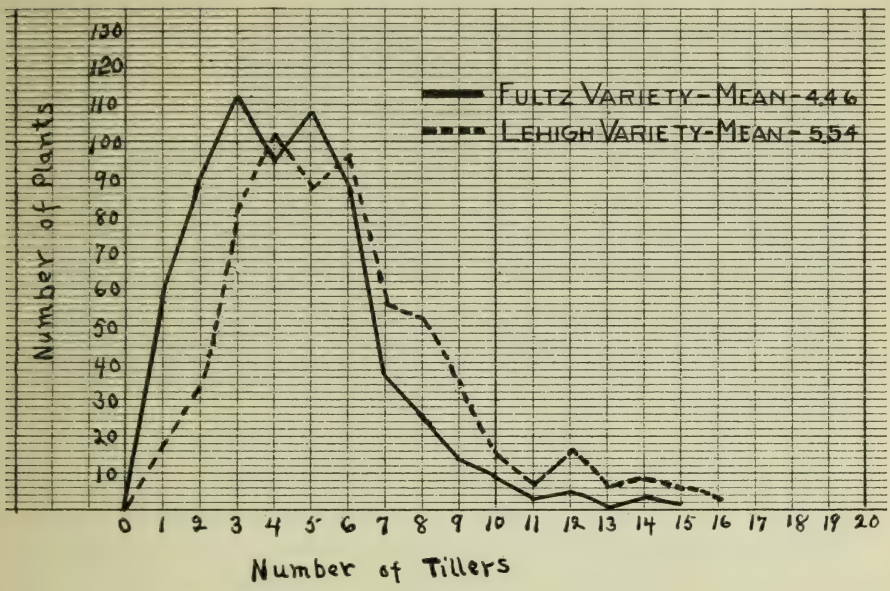

FIG. 2.—Curves showing mode and mean of number of tillers in Fultz and Lehigh varieties of wheat.

TABLE IV.—*The Relation of the Number of Tillers Per Plant to Length of Culm and Spike and to Yield and Quality of Grain Per Spike in Wheat, Based on an Average of Ten Plants in Each Group.*

Variety and No. of Tillers per Plant.	Av. Length of Culm.	Av. Length of Spike.	Total Yield of Grain from Ten Plants.	Total Yield of Straw.	Yield of Grain per Spike.	Number of Kernels in Five Grams.
GYPSY.	*Inches.*	*Cm.*	*Grams.*	*Grams.*	*Grams.*	
2	37.5	7.2	8.0	16	.40	237
3	38.6	7.9	17.0	26	.56	199
4	41.6	8.0	31.8	40	.79	171
5	42.4	8.9	42.9	58	.85	185
6	43.5	8.4	47.0	80	.78	184
7	42.1	8.5	55.8	90	.79	185
8	40.6	9.0	72.0	105	.90	185
9	42.6	8.8	78.4	124	.87	174
10	41.1	8.3	84.0	146	.84	165
EARLY RIPE.						
2	33.2	7.1	13.5	14	.67	161
3	34.1	7.1	21.0	29	.70	165
4	35.2	7.8	32.0	47	.80	154
5	38.1	7.6	40.3	65	.80	145
6	41.1	8.1	61.8	75	1.03	126
7	37.2	8.4	69.6	88	.99	126
8	39.5	7.8	72.6	118	.80	132
9	40.2	8.0	84.5	127	.93	133
10	40.8	8.3	98.4	141	.98	130

The most marked increase is in the yield per spike which is more than doubled in the plants having the larger number of tillers. The increase in yield per spike is accompanied by an increase in the weight of the kernel. In the Gypsy variety the kernels of the 2-tiller plants are much smaller than those from the stronger tillering plants. The increase in the number of tillers per plant from 2 to 10 has raised the yield per spike in the case of the Gypsy variety from .40 gram to .84 gram. At the same time the increase in the length of culm was only 3.6 inches, and the increase in the length of spike 1.1 centimeters. This verifies the earlier statement in this paper that the wheat plant, if given room for development, will respond in a wider ratio through the increase in the number of tillers than by increasing the length of culm and spike or yield of grain per spike.

In conclusion, the data indicate that tillering expresses the capacity of the plant for development, and if, as shown above, increased yield per spike is associated with plants with the larger number of tillers, then those varieties which have the higher coefficient of tillering should be the more dependable for high yields. The planting of varieties so that each plant will develop separately and uncrowded puts to the test the capacity of the variety for asserting itself in production. It seems clear that when certain varieties tiller so much better than others under the same conditions of soil and season, that the more vigorous varieties will yield better on a poor soil, or the weaker tillering varieties will be put at a disadvantage by overcrowding if sown at the same rate as the higher tillering varieties.

From this it may be inferred that wheat varieties as usually tested by sowing at the same rate per acre are not subject to the same conditions of development, as the variation in the size of kernels among varieties is so wide that a much larger number of kernels of one variety than another is sown on a given area. Should some of the low tillering varieties have small kernels, then it is evident that a larger number of plants would result from the sowing. The question naturally arises as to the best rate of sowing for the different varieties as well as the proper variety for different soil conditions. This can only be answered by further work along this line. Results thus far indicate that the method of studying wheat varieties by the individual plant affords certain advantages in determining the desirable qualities of wheat. This would put at a still greater disadvantage the weaker tillering varieties or the varieties which have been shown to develop less freely in open, individual plantings.

SUMMARY.

1. Varieties of wheat vary widely in the habit of tillering, which is apparently a varietal characteristic.

2. With tillering there seems to be associated vigor and a capacity on the part of the plant for better development under unfavorable conditions.

3. Tillering is a character of the wheat variety which appears more or less constant; the high tillering varieties not only yielding better under poor conditions, but also surpassing the low tillering varieties under optimum environment.

4. An increase in the number of tillers per plant within a variety as well as among varieties is accompanied by higher yield per spike.

5. A greater length of spike and of culm is found with the high tillering plants.

6. The quality of the grain is closely correlated with the development of the plant as expressed by the number of tillers.

7. The vegetative activities of the wheat plant are expressed more widely by the increase in the number of culms or tillers than by the increase in the length of culms or length of spike.

THE EFFECT OF SELECTION IN PURE-LINE OAT WORK.

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Presented at the Lansing Meeting, July, 1912.

The object of this discussion is to give additional evidence on an old problem. It is not likely that it will do more than to strengthen your present views. The Michigan Experiment Station has some evidence in oats that should be in the hands of all.

The problem, to state it more clearly, is as follows: We plant individual oat seeds so that these seeds may have equal chance to grow into separate plants. We make individual selections that are to become mothers of pure lines. These lots are planted in separate plots and the seeds are also planted individually, that individual selection may be made from these pure lines in the following year. This process is continued yearly for a period of say ten years. Each year the line of descent passes through a selected individual plant. Each year the aim is to select the best. At the end of that time, will the

TABLE I.—*Heredity in American Banner Oat, Showing Results of Continued Selection Within Pure Lines from 1900 to 1910. Average Yields for 1909 and 1910 Only.*

1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	Av. Yield.
					Family No. 1. Poor.						
00101	10102	20101	30101	40803	50101	60301	73601	85100	Dropped.		

Each year Prof. Jeffery had selected a plant, hoping to improve the strain, but selection failed.

					Family No. 7. Good.						
00107	10701	20301	30301	40904	50201	60401	73700	89000	910900	09600	59.5 Bu.
							73702	81302	90502	00400	
	10702	20301	30301	41601	50302	60501	73800	89100	910800	09700	59 Bu.

These strains were considered practically identical and in 1912 only 60401 planted.

					Family No. 10. Poor.						
00110	11001	20501	30501	41204	50501	60701	74000	Dropped as generally undesirable.			
	11002	20601	30601	41101	50602	60801	74100				
				41102	50702	60901	74200	Dropped like above.			
	11003	20701	30701	41003	50801	61001	74300	810400	911000	09900	56.3 Bu.
				41004	50901	61101	74400	89400	911200	010100	55 Bu.

Three sister plants became mothers of individual lines in 1901. The last of these were dropped in 1910 as poor in quality and yield.

					Family No. 12. Good.						
00112	11202	21101	31001	40501	51001	61201	74500	89500	911300	010200	62.7 Bu.
				40502	51101	61301	74600	810600	911400	010300	61.4 Bu.

These strains were considered practically identical and in 1912 only 61201 planted.

					Family No. 14. Poor.						
00114	11402	21401	31301	40602	51202	61401	74700	89600	911500	010400	57.2 Bu.
							74702	82300	99900	012100	56.3 Bu.
							74710	82500	910000	012200	57 Bu.
								82502	90705	00600	

Prof. Jeffery had hoped to improve by selection. All lines dropped in 1911 as unproductive.

					Family No. 15. Good.						
00115	11502	21501	31401	40102	51303	61501	74800	810700	913300	010600	65.7 Bu.
				40103	51401	61601	74900	810800	913400	Check.	66.9 Bu.

These strains were considered practically identical, and in 1912 became known under the name Alexander. This is Prof. Jeffery's middle name.

					Family No. 16. Poor.						
00116	11601	21601	31601	40203	51501	61701	75000	Dropped, gen. undesirable.			
					51502	60601	73900	89200	910900	09800	58 Bu.
				40204	51601	61801	75100	Dropped, gen. undesirable.			
	11602	21701	31701	40301	51701	61901	75200	"		"	
				40302	51801	62001	75300	"		"	
				40303	51902	62101	75400	"		"	

This family had branched considerably when it came to us in 1907, but only one strain was ever increased to yield tests. It was dropped as unproductive.

good lines remain good and the poor lines remain poor, or will certain lines from poor families be so improved as to take a place among the good lines?

The station has evidence in several varieties, but as that evidence is more extensive in American Banner, our discussion will be confined to this variety. It will suffice to say that the data obtained from other varieties simply confirm what American Banner shows.

The selection work in American Banner oats was started by Professor J. A. Jeffery in 1900. In that year he made his original selections, obtaining something more than sixteen individual plants that were to become mothers of his pure lines. He continued his selection work from plant to plant until 1907, when it was turned over to the writer.

In 1900 Professor Jeffery had just one plot planted from the seed of the variety American Banner. From this he made his selections. Only family or pure line numbers: 1, 7, 10, 12, 14, 15, and 16, are given on the chart. The other lines had been dropped by Professor Jeffery before 1907, as undesirable. The seven remaining were increased and tested in varietal plats, 1908–1911, inclusive. In 1908 these were thrashed by hand, and as the loss of seed is known to have been heavy in some cases, the resulting yields are not used in the average. As not all the strains were present in 1911 the data for that year are not used with the others, which are given in Table I.

It may be well enough to explain the register numbers used in this connection. In each case the first figure stands for the year; the next two figures give the plot number of that year; and the last two figures give the selection number. For example, 61601 is the first selection from the sixteenth plot grown in 1906. Examining the chart, it will be noticed that all the register numbers, in any vertical column, begin with the same figure as the date ends with.

Taking a little time to examine the chart, it will be found that some of the poor families had been allowed to branch considerably, but in a poor line all the branches are poor to the end, and vice versa.

SEED COLOR IN RED CLOVER.

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Submitted for publication in December, 1912.

The occurrence of "red" clover plants (*Trifolium pratense*) having white blossoms, and others having nearly white blossoms, is rather frequent in regions where clover has become well established.

In the summer of 1910 the writer marked, for propagation, 25 plants differing in flower color. The majority bore white flowers with a red tinge of varying intensity, while a few of the plants selected produced blossoms apparently pure white and other plants displayed flowers of a very dark red color. It was intended to make a flower color representation of each plant for permanent record, but other work prevented this as well as descriptive notation while the plants were in bloom.

Some of the plants selected were found in grass sod along driveways in the vicinity of Champaign, Illinois, where the vegetation surrounding the marked plants was mowed frequently; the marked plants being, therefore, fairly well isolated. The remaining plants were found in clover fields and thus exposed to the pollen from other clover plants during the blossoming period. At maturity the twenty-five plants were harvested separately and stored until further study could be devoted to them.

In the spring of 1912 the study was resumed in a limited way. Five of the plants were hulled separately and the remaining twenty were hulled in composite. Small quantities of the six samples of seed were germinated and the plantlets thus obtained were started in individual pots in the laboratory. These were afterwards transferred to six widely separated situations in a twelve-acre field of corn for the purpose of again selecting individuals differing in flower color and other characters.

The writer has no conclusive results to report at this time upon the behavior of the various characters he has observed during the progress of this interrupted study upon red clover. However, it seems worth while to mention some of the facts learned concerning the color of the seed in order that they may come to the attention of others interested in the subject.

Although the early part of the season of 1912 was not favorable to the growth of clover, nearly all the settings grew nicely until discov-

ered by rabbits who made stamping grounds of these isolated clover plantings in the corn. It was rather late in the season before time was found to protect what remained with woven wire and, because of this, seed was obtained only from a small number of individuals.

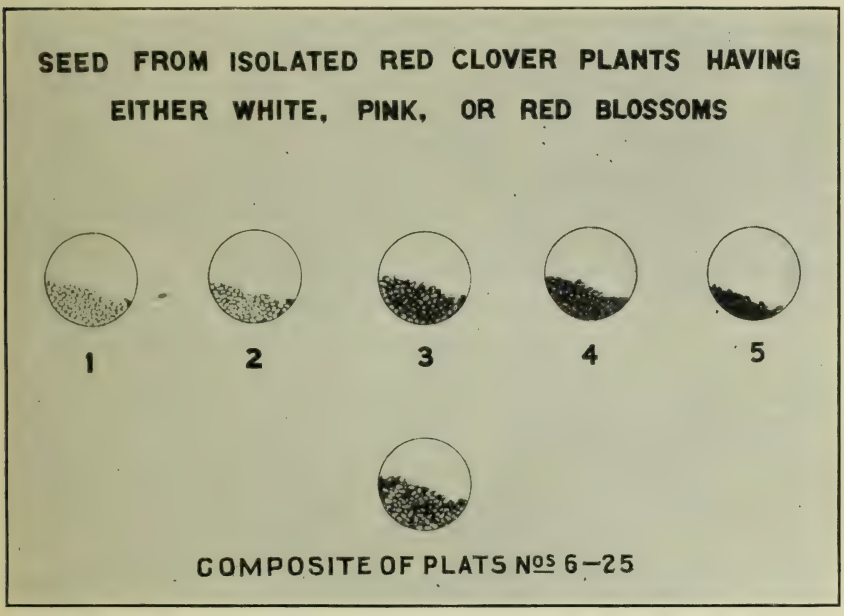

FIG. 3.—Color of the seed from twenty-five isolated red clover plants having either white, pink or red blossoms. Nos. 1–5 shown separately; Nos. 6–25 as a composite sample.

It happened that the five parent plants selected at random for isolation all differed from each other in seed color (see Fig. 3), and these five apparently covered the whole range of color in the composite of the remaining twenty plants.

The seed colors of these parent plants were as follows:

Plant No.	Color of Seed.
1	Pea
2	Purple tint on yellow
3	Reddish purple on yellow
4	Medium purple on yellow
5	Dark purple on yellow
6–25	Preponderance of No. 2, with some colors of Nos. 1, 3, 4, 5

Another prominent feature of the first five samples was the uniformity of color within each sample (only chaffy and poorly developed

seeds were discarded in hulling) although it was expected that at least some of the plants were hybrid with respect to seed color, etc. (and purple probably dominant to non-purple), or that considerable mix-fecundation had taken place in the season when they were selected, it was anticipated that each of the progeny would produce seeds the majority of which would be similar in color to that of the parent from which they came. The results are shown in Table I.

TABLE I.—*Color of the Seed of Various Progeny in the 1912 Crop from Five Clover Plants.*[1]

Family No. of the Five Plants and Color of Seed of the Parent Plant.	Color of Seed and Number of Plants in Each Family with Seed of that Color.										
	Pea (1).	Yellow.	Very Faint Tint on Yellow.	Purple Tint on Yellow (2).	Reddish Purple on Yellow (3).	Medium Purple on Yellow (4).	Light Purple on Yellow.	Purple on Yellow.	Dark Purple on Yellow (5).	Dark Purple on Yellow Evident.	Total.
1 (pea)	**0**	3	1	1				3			8
2 (purple tint on yellow)		8	7	**3**	1		6	2			27
3 (reddish purple on yellow)				3	**0**	1	2	2			8
4 (medium purple on yellow)				5	3	**5**	9	10	2		34
5 (dark purple on yellow)			1					1	**1**		3
Totals		11	9	12	4	6	17	18	3		80

As is apparent in the table, the number of individuals finally producing seed was quite limited and the colors somewhat scattered. The observed behavior of seed color displayed by these five families might be attributed to one or more of the following: (*a*) The five parents used may have been hybrids; (*b*) the seed produced by the parents may have been mix-fecundated; (*c*) the color may be affected by mix-fecundation in the same season in which the seed is formed (by xenia); (*d*) purple may have been latent, or failed to develop on the individuals producing yellow seed; (*e*) inheritance of the colors may be inconstant and fluctuating in reproduction.

Nothing is known, as yet, to disprove (*a*) and (*b*), in fact, all the strains were found to be apparently hybrid with respect to characters other than seed color. The individual uniformity of seed color in all the plants observed in the two seasons corroborate the reports of other investigators—that the plant and not the seed is the unit for the inheritance of seed color. Therefore, xenia plays no part in the pres-

[1] Bold-faced figures in the table indicate the position that all the progeny of the family concerned should have occupied had each parent and its progeny been pure lines with respect to seed color, provided seed color is inherited precisely and constantly.

ence or absence of purple in clover seed and the color, when present, is located in the seed coat and not in the endosperm remnant nor in the embryo (as has also been shown anatomically by others).

No individuals have yet been found in which the seeds were entirely purple. There is usually an area on the seed in which the purple is not sufficiently dense to conceal the yellow groundwork of the layer of cells in which the purple pigment is deposited. When clover seed is harvested immaturely it shows little or no purple and is usually white or pea color, which may change to yellow, especially when the seed is cured improperly. Seeds lighter in color are frequently found at the tip and extreme base of the head; this being no doubt caused by poor development and immaturity. The purple pigment is soluble but breaks down in water without coloring the liquid. Brown seeds, due to unfavorable conditions in maturing and storing, are indication of poor management and consequently of low viability.

The writer has found numerous instances in corn where purple fails to develop sufficiently in the aleurone to be detected by the eye. It is quite evident that this occurs in red clover also. Of the 11 individuals classed as yellow in the table, 4 cases were found in which a trace of purple existed.

Commonly in corn, when white is hybridized with white, one expects and obtains white seed in the progeny, but instances have been reported (the writer has found a number of such cases) in which purple is developed in definite ratios when certain pure strains of white corn are hybridized. The writer has also found several strains of yellow corn that produce similar results when hybridized with others having this purple developing factor in one form or another. Purple kernels secured in this way by hybridizing yellow or white strains, when homozygous, will produce solid purple or "blue" ears in the progeny.

There are other instances in corn where the purple is broken, giving a mottled or spotted appearance. Other numerous instances were found where purple hybridized with its absence develops a certain percentage of red or reddish purple aleurones.

The development of purple and reddish purple through hybridization by new combinations, where none was visible before, may probably occur in clover as in corn. The many shades of purple, including the reddish purples, may complicate the analysis of seed-color inheritance in clover.

The finding of no pea-colored seeds in the progeny of family No. 1 may be attributed to the exposure of the seed in the field. Pea color oxidizes readily to yellow. The seed was not harvested in 1912 till

long after frost and numerous fall rains, while in 1910 the season was dry and the plants were gathered soon after the seeds were matured. Similarly, no pea-colored seeds were obtained from the composite planting (Nos. 6–25), but numerous yellow and purple types were obtained.

Since the parent seed of family No. 1 exhibited no purple, it is apparently a plain case of mix-pollination in the season when the parent seed was produced, or of segregation and dominance of purple over yellow where the purple is inhibited in the first generation. Two of the three yellows were doubtful and it is possible that they will produce some individuals having purple seeds in the next generation.

By transferring two rather doubtful individuals classified as yellow in family No. 2, the ratio would be 21 purples to 6 yellows, but as the ratio stands it is 19 purples to 8 yellows.

These instances are of little value in establishing a Mendelian ratio, but they suggest a simple (1:2:1) type of segregation. In all the counts from mixed populations of purple and yellow clover seed that have come to the writer's notice, the purples have been generally in the large preponderance over the non-purples. Since the separation of the poorly developed purples from the yellows is associated with uncertainty, it is quite probable that in perfect separations the ratios would approximate 3:1. Unless a character is favored by natural or artificial selection its preponderance in a mixed population establishes its dominance, genetically. While purple-colored clover seed is at a premium on the market, there certainly has never been enough discrimination in favor of purple color to overcome the balance of possible dominance of non-purple.

There is a popular demand for purple-colored clover seed, the general impression being that purple color indicates maturity, viability, and vigor. It is quite well established that purple in clover seed has no relation to yield, either of seed or hay. Equally high yields have been obtained from the progeny of both yellow and purple seeds.

It was found that white-flowered plants always produced yellow (or pea) seeds. Some of the pink and light red-flowered plants also produced yellow seeds, while the seeds from dark red flowers were invariably dark purple. Thus it seems that seed color is coupled more or less with flower color in clover, but the true relation is not yet definitely understood. It seems entirely feasible to cater to the popular demand for purple seed by selection, using both blossom and seed color as indices in propagation.

This study upon clover forms a part of general preliminary work undertaken by the writer in relation to leguminous crops for the pur-

pose of developing a technic of breeding for this extensive and invaluable family of plants. Since clover is commonly mix-pollinated, complete isolation is essential in breeding operations for the purpose of studying inheritance and for the development of pure lines possessing certain desired characters.

Charles Darwin's memorable experiment and deduction concerning the bumble-bee as a pollinating agent in red clover has been definitely overthrown. This instance may be relegated to the same category as that in which the number of old maids in a community govern the number of cats, which determine the number of mice (provided they are working cats) which feed upon bumble-bee homes and larvæ, consequently affecting the number of bumble-bees escaping from the mice; the frequency of maids, therefore, controlling the price of clover seed in the community. While both maid and bee might regulate clover seed production in a given instance, as it is possible the bees actually did in the observation recounted by Darwin, we know that control by these two strenuous factors is hardly the general rule in determining the yield of clover seed at least.

The writer had occasion to pass daily the six strains as well as other isolated clover plantings in the corn during the season of 1912. With the exception of a single plant located at the edge of the field, the true bumble-bee (*Bombus*) was never discovered visiting the plants in question, and yet many of these plants produced large quantities of seed. Other species of bees as well as numerous moths, thrips, and other small insects were found at work on the blossoms.

It is quite certain that nearly all the seed obtained from these plants must have been produced without the aid of bumble-bees. Instances have been published and others recounted to the writer, on reliable authority, where good yields of seed have been obtained from fields of red clover blooming early in the season (first crop) before bumble-bees appear in numbers of any consequence.

In cases of isolated red clover plants, it is quite well established that insects of some kind or violent agitation of the blossoms is required for their pollination, because of the peculiar structure of the flower. When insect pollinators are scarce it becomes necessary to trip the flowers artificially, which is the most reliable method of producing pure seed. Propagation by cuttings may be resorted to where no seed is secured, but this method is somewhat limited in its application.

Shading the plants with bags or netting is unfavorable to the development of seed, in addition to excluding various insects that serve as pollinators for the blossoms. The common method of isolation by distance and by other crops intervening, or by means of natural

barriers, is probably the most satisfactory method where it is desirable to produce a maximum quantity of seed.

When one attempts to control a character in plant or animal, he may most speedily and economically learn how by means of hybridization. (An investigator is not truly scientific who fails to economize his resources,—science and economy go hand in hand.) The writer is Mendelianist by necessity rather than by design, and has come to the conclusion that the isolation of pure strains or lines, followed by their recombination through hybridization, is the most rapid and surest way to a perfect understanding of the possibilities of improvement in our economic plants and animals.

With the exclusion of "performance record" and possibly the half truth—heterozygosis, no selectionist, in all the years gone past, has yet put his finger unequivocally upon a single factor or set of factors in the structure of an individual correlated with or enhancing yield.

By hybridization we are enabled to grasp previously unapprehended possibilities which influence the course of a character in general culture. Not only its behavior toward other characters, but its combination into new or perhaps more desirable arrangement is thus suggested and new structures may be built from parts of the old. Thus, also, specially desirable combinations, whether of quantity or quality, may be perpetuated and the undesirable eliminated.

In this connection, negative results may be of as great value, economically and scientifically, as positive issues. The final goal in such work is *exact control*. Nature may be "wasteful" (as has been said) in mixed populations, but never in controlled pedigrees where her craft is sure and swift.

A STUDY OF RED CLOVER SEED WITH RELATION TO ITS COLOR.[1]

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INTRODUCTION.

The difference in the color of clover seed is very noticeable. There are seeds which are of a bright yellow and others which are of a deep violet or purple color. Between these two colors there are all shades and gradations, from a yellow with just a little dark color showing, to others with enough of the dark color to make a spotted seed, and still others with enough to make a deep violet. Farmers, and consequently seedsmen, prefer seed of a dark color because they believe it looks more mature and appears richer in food material. This difference of color is illustrated in a large number of different kinds of seeds. In general, seeds of a dark color are associated with maturity, while the white or lighter-colored seeds are considered immature.

This character of color may be the result of either or both of two general causes, viz., internal or external. Thus, if the character is the result of an internal influence we should expect it to be inherited, and if purple seeds were planted we should secure, after a few generations, plants bearing a very large proportion of purple seed. In the same way, yellow or any other color would be inherited provided that no external influence entered in.

The external factors which might influence the color of the seed are food supply, seasonal variations of temperature, rainfall, and varying amounts of sunlight which individual plants receive. All of these factors have their effect upon the development of a plant and the complete maturity of its seed.

HISTORICAL.

Menke and Hillenmeyer[2] divided clover seed into six different classes according to color and sowed the same number of seeds of

[1] Portion of a thesis submitted to the faculty of the Graduate School of the University of Illinois, in partial fulfillment of the requirement for the degree of Master of Science.

The author wishes to express his appreciation of the kindness and encouragement of Dr. L. H. Smith, of the University of Illinois, under whose direction the experimental part of this work was carried out and also his indebtedness to others who assisted in various ways.

[2] Menke, A. E., and Hillenmeyer, H. F., Clover. Kentucky Exp. Sta. Bul., 6: 6–7.

each under identical conditions. Their results indicate that yellow seed germinated the best and produced the healthiest plants.

Beal[3] says that, "The results obtained on testing numerous samples in different seasons indicate that there is no difference in favor of the dark seeds either in vitality or the quality of the plants which they produce." Preyer[4] found that in samples of seed representing several species of *Trifolium* there was a greater proportion of violet and mixed colored seeds than yellow. Variously colored seeds did not differ with respect to ash, density, and water content. Germination tests showed that in nearly all cases the light colored seed germinated much better than the dark seed. Plants from yellow seeds yielded very much heavier than the plants from dark seeds. The color of the seed seemed to be inherited.

Schribaux[5] found that the first ripened seeds were heavier and darker in color. Von Rümker[6] discovered that yellow seeds are heavier and give plants which are much more productive than plants from differently colored seeds. Fruwirth,[7] in an examination of clover heads, found that the heavier seed are located in the lower part of the head and that there is a gradual decrease in kernel weight toward the top of the head. He found[8-9] that the plants from yellow seed gave a higher yield of air-dry matter than plants from either spotted or dark violet seed and that they bore white flowers. Fischer[10] believes the seed color to be inherited.

Card[11] has shown that there is no difference between the nitrogen content of plants produced from purple seed and those grown from yellow seed.

Experimental.

The investigations regarding the relation of color in red clover seed consist of the following:

1. A study of the location of the seed in individual heads with respect to weight, color, and inheritance of color.

[3] Beal, W. J., Grasses of North America, 1: 340.

[4] Preyer, A., Ueber die Farbenvariationen der Samen einiger Trifolium-arten (Inaug. Diss., Berlin, 1899), abstr. in Bot. Centralbl., 81 (1900): 243–245.

[5] Schribaux, E., Contribution à l'amélioration du tréfle des prés. Jour. d'agr. pratique, 1: 576. 1896.

[6] von Rümker, K., Das landwirtschaftliche Unterrichtswesen in Frankreich. Landw. Jahrb., 1893, p. 204.

[7] Fruwirth, C., Ueber Samenfarben und Samenschwere in einzelnen Köpfen bei Rotklee. Landw. Versuch. Stat., 55: 439–452 (1901).

[8] Fruwirth, C., Die Züchtung der landwirtschaftlichen Kulturpflanzen, 3: 167.

[9] Fruwirth, C. (abstract), Exp. Sta. Rec., 14: 30. 1902.

[10] Fischer, M. (abstract), Exp. Sta. Rec., 14: 855. 1903.

[11] Card, F. W., Clover selection, R. I. Exp. Sta. Rept., 1907: 214–220.

2. The influence of soil fertility upon the proportions of dark and light colored seed.

3. A comparison of the apparent viability, weight, specific density, and composition of purple and yellow seed.

4. The location of the coloring matter in the purple seed and the effect of different solvents upon it.

5. A comparison of the plants produced from purple and yellow seed.

Location of the Seed in Individual Heads and Its Relation to Weight, Color, and Inheritance of Color.

Most of the plants from which the heads were taken for this study were produced at Urbana, Illinois, on the plots of the Illinois Experiment Station. The season of 1909 was the third year in the life of the plants so that they now represent a perennial rather than a biennial form of clover. The maternal parents of these plants are given under the discussion of the inheritance of color. It should be noted that they were all produced from dark seed.

The seed was separated into three main groups; the first a dark purple, the second an intermediate class, including all seeds with some purple and some yellow on them, and designated as purple-yellow, and the third, the yellow seed. The seed head to be examined was either cut in halves and the proportions of purple, purple-yellow, and yellow seed determined, or, commencing at the base, the individual seed were taken out one at a time.

In a study of the results of this work we find that neither the individual head nor the plant bear uniformly colored seed. Certain plants seemed to bear all yellow seed, but a close examination shows that some of this seed is of a somewhat darker color. The darker colored seed is found in the lower part of the head. In plants and heads bearing yellow seed, usually a portion of the seed is found to be immature. No plants or heads have been found bearing all dark seeds. There are always some seed of a lighter color in the upper part of the head. The results of examination of a large number of heads show that there are nearly twice as many dark seeds in the lower part of the head as in the upper part. And in the upper part of the head there are nearly twice as many light seed as dark. In other words, in the upper part of the head the ratio of dark seed to light is as 1.932:1, while in the lower part of the head it is as 2.1166:1.

A review of the weights of the variously colored seed in the upper and lower parts of the clover heads brings out some interesting points.

TABLE I.—*Number of Purple, Purple-Yellow and Yellow Seeds Found Respectively in the Upper and Lower Part of Heads of Twelve Different Red Clover Plants.*

Plant No.	Upper Part of Head.			Lower Part of Head.		
	Pur.	Pur.-yel.	Yel.	Pur.	Pur.-yel.	Yel.
107 *A*	17	112	99	23	213	68
107 *B*	3	246	129	15	250	104
108 *A*	2	21	14	—	18	21
108 *C*	—	20	43	—	31	34
108 *D*	—	30	24	9	25	18
109 *A*	—	24	137	7	37	116
109 *D*	—	16	18	—	18	7
113 *B*	11	8	2	10	11	—
113 *A*	130	80	150	223	109	137
113 D	7	7	15	26	38	8
209 *B*	7	27	12	13	29	4
209 *D*	—	4	4	—	2	6
Totals	177	595	647	326	781	523

Ratio of Dark to Light Seed.

Upper part of heads ..... 1.1932 : 1.

Lower part of heads ..... 2.1166 : 1.

TABLE II.—*Weights in Grams of Seed of Different Colors from Upper and Lower Parts of Several Heads from Different Plants of Red Clover.*

Plant No. and Source of Seed in Head.	Number and Weight of Seed of Each Color.					
	Purple.		Purple-yellow.		Yellow.	
	No. of Seed.	Weight of Seed.	No. of Seed.	Weight of Seed.	No. of Seed.	Weight of Seed.
Plant No. 107 *A*.		*Grams.*		*Grams.*		*Grams.*
Upper part	9	.0123	75	.0956	28	.0290
Lower part	10	.0147	160	.1959	8	.0107
Plant No. 108 *D*.						
Upper part	0		30	.0405	34	.0367
Lower part	9	.0122	25	.0318	45	.0398
Plant No. 109 *B*.						
Upper part	0		0		51	.0495
Lower part	0		0		81	.0902
Plant No. 109 *D*.						
Upper part	0		16	.0193	18.	.0207
Lower part	0		18	.0229	7	.0075
Plant No. 113 *B*.						
Upper part	11	.0150	8	.0106	33	.0337
Lower part	10	.0140	11	.0141	32	.0399
Plant No. 113 *D*.						
Upper part	7	.0113	7	.0099	15	.0162
Lower part	26	.0429	38	.0509	8	.0089
Totals, six plants						
Upper part	27	.0386	136	.1759	179	.1858
Lower part	55	.0838	252	.3156	181	.1970
Average kernel weight		(*mg.*)		(*mg.*)		(*mg.*)
Upper part	1	1.4300	1	1.2933	1	1.0380
Lower part	1	1.5236	1	1.2524	1	1.0884

The weights reported are in all cases for plump seed. It will be seen that occasionally individual yellow seed weigh heavier than others of a darker color. A summary of the results proves that the average kernel weight of purple and yellow seed in the lower part of the head is greater than the average kernel weight of seed of the same color in the upper part of the head.

The question of inheritance of color is a difficult one to decide, for there are several factors which must be considered. Table III indicates the color of seed in the heads of the dams of the plants recorded in Tables I and II.

TABLE III.—*Color of Seed in Mother Plants,*[12] *Register Numbers 107, 108, 109 and 113.*

Plant No.	No. of Heads.	No. of Dark Seed.	No. of Light Seed.	No. of Culls.
107	10	1,497	59	432
	Remainder	893	475	1,175
109	10	615	36	105
	Remainder	272	78	718
108	10	587	130	105
	Remainder	1,074	123	1,069
113	10	755	0	157
	Remainder	502	0	280

The dark seeds from six heads of each of the plants reported in Table IV were planted in the spring of 1907. A number of the progeny of three of these plants were examined in 1908 with respect to the proportion of light and dark colored seeds found in the heads.

TABLE IV.—*Proportion of Dark Seed in Twenty Plants*[13] *from the Progeny of Each of Three Different Mother Plants.*

Plant No. 107.		Plant No. 109.		Plant No. 113.	
No. of Plants.	Color of Seed.	No. of Plants.	Color of Seed.	No. of Plants.	Color of Seed.
16	85 per cent. dark	9	87 per cent. dark	10	98.5 per cent. dark
4	Medium dark	5	Medium dark	4	Medium dark
		4	Medium light	2	Medium light
		2	Light	4	Light

It will be seen from Table IV that plants from dark seed do not all produce dark seed. The results appear to indicate that color is controlled by external as well as internal influences and that it is inherited to the extent that maturity of the seed is inherited.

[12] Not examined by the writer.

[13] Not examined by the writer.

Effect of Soil Fertility Upon the Proportions of Dark and Light Colored Seed.

In a study of the relative amounts of dark and light colored seeds produced on soils of varying fertility, I was able to secure seed from several plots in Series 300 of the soil fertility field of the Illinois Experiment Station, located just east of Matthews Avenue, in Urbana. The crop of seed from the two halves of the plots was harvested separately. A sample of four grams of seed was examined from several of the plots; two grams from the east half and a like amount from the west half. They were taken by number, without paying any attention to the fertilization of the plots from which they were produced. The seed was separated into three lots; the first containing the dark or purple seed, the second the yellow seed, and the third the inert matter.

Table V.—*Influence of Fertilizer Treatment of the Soil upon the Proportion by Weight of Purple and of Yellow Seed in Red Clover.*

Plot No.	Portion of Plot.	Fertilizer Treatment.	Purple Seed.	Yellow Seed.	Average for Both Halves.	
					Purple Seed.	Yellow Seed.
			%	%	%	%
2	East	Legume	37.8	62.2	35.1	64.9
	West		32.4	67.6		
5	East	Manure and lime	36.8	63.2	34.5	65.5
	West		32.3	67.7		
6	East	Legume, lime and phosphorus	52.4	47.6	49.	51.
	West		47.34	52.66		
7	East	Manure, lime and phosphorus	43	57		
	West		43.4	56.6	43.2	56.8
8	East	Legume, lime, phosphorus and potassium	49.4	50.6		
	West		50.6	49.4	50	50
9	East	Manure, lime, phosphorus and potassium	42.2	57.8		
	West		47.3	52.7	44.7	55.3
10	East	Legume, manure $(\times 5)^{14}$	39.4	60.6		
	West	Lime, phosphorus $(\times 5)^{14}$	42.4	57.6	40.9	59.1

The amount of purple and yellow seed in each lot was determined by weight.

The results indicate that the plants showing the larger proportion of purple seed in all cases received phosphorus and lime. The two having the highest percent of purple seed received a treatment of

[14] $\times 5$ indicates extra large quantities of manure and phosphorus.

phosphorus, lime, legume and potassium. The largest amount of yellow seed was produced on plots receiving manure or a legume, which furnish an abundant supply of available nitrogen. A treatment with legume or lime seems to have no effect on the amount of purple seed unless these are supplemented with phosphorus. It has been found that an abundant supply of available phosphorus in the soil aids a plant in maturing its seeds promptly, while an abundant supply of nitrogen causes a plant to keep on growing and producing new foliage, instead of maturing its seed. The element of plant food most deficient in this soil is phosphorus, and there are sure indications that the proportion of purple and yellow seed is influenced to a considerable extent by it.

Viability of Purple and Yellow Seed.

A germination test was made of 1,400 purple and 1,400 yellow seed. The dark seed selected were of a deep purple color, while the light seed were of a bright yellow. The seed were of a uniform size and plump appearance.

Table VI.—*Germination of Purple and Yellow Seed of Red Clover and Percent of Hard Seed in Each Sample from Plots Fertilized Variously.*

Sample from Plot No.	Percent Germinated.		Percent Hard Seed.	
	Purple Seed.	Yellow Seed.	Purple.	Yellow.
	Percent.	*Percent.*	*Percent.*	*Percent.*
2 E	83.5	83.5	16.0	15.5
2 W	79.0	84.5	20.0	11.5
5 E	82.5	75.5	16.5	20.5
5 W	84.0	75.0	16.0	18.0
6 E	85.5	83.5	14.0	15.5
6 W	88.5	87.0	9.0	10.6
7 E	83.0	75.0	16.5	24.0
7 W	81.0	79.5	18.0	15.0
8 E	85.5	80.0	14.0	18.5
8 W	83.5	79.5	16.0	18.5
9 E	87.0	79.0	18.0	19.0
9 W	90.5	86.0	8.5	12.5
10 E	86.0	87.0	11.5	10.5
10 W	85.5	85.5	14.0	14.0
Average.....	84.2	81.5	14.86	15.96

Table VII.—*Germination of Purple and Yellow Seed of Red Clover, Showing Percentage Germinating Each Day for Seven Days.*

Day.	1st.	2d.	3d.	4th.	5th.	6th.	7th.
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
Purple....	32.22	35.76	13.07	2.25	0.78	——	0.14
Yellow....	29.22	35.86	12.72	2.96	0.42	——	0.14

The germination tests show that 2.7 percent more purple seed sprouted than yellow. The purple seed germinate a little faster than the yellow. The yellow seed seem to have more hard seed, there being a difference of 1.1 percent.

Comparison of the Weights of Purple and Yellow Seed.

Before starting the germination tests previously reported, each lot of 200 seeds was weighed. The results are shown in Table VIII.

Table VIII.—*Weights of Purple and Yellow Seed.*

Source of Seed.	No. of Seed Weighed.	Purple Seed.	Yellow Seed.
		Grams.	*Grams.*
Plot 302 E	200	.2817	.2708
302 W	200	.2863	.2666
305 E	200	.2968	.2597
305 W	200	.2957	.2668
306 E	200	.2852	.2739
306 W	200	.2915	.2630
307 E	200	.2832	.2665
307 W	200	.2961	.2672
308 E	200	.2733	.2559
308 W	200	.2767	.2549
309 E	200	.2950	.2609
309 W	200	.2928	.2635
310 E	200	.3072	.2820
310 W	200	.2791	.2627
Totals	2,800	4.0406	3.6944

These results indicate that in every sample the 200 purple seeds are heavier than the 200 yellow seeds.

The weights of purple and yellow seed from different heads and plants were also taken. It should be noted that Table IX gives the *average kernel weight.*

Table IX.—*Average Kernel Weight of Purple, Purple-Yellow and Yellow Seed from Different Plants and Heads.*

Plant No.	Head No.	Purple.		Purple-yellow.		Yellow.	
		No. of Seed.	Average Weight.	No. of Seed.	Average Weight.	No. of Seed.	Average Weight.
			Mg.		*Mg.*		*Mg.*
107 *A*	2	2	1.6	71	1.4253	12	1.275
	3	—	—	27	1.6074	5	1
	5	17	1.4	28	1.2143	19	1.021
107 *B*	All	42	1.19	856	1.151	317	.956
108 *D*	3	9	1.355	39	1.354	12	1.075
109 *D*	1	—	—	34	1.24	25	.9915
113 *A*	All	353	1.52	244	1.17	310	1.24
113 *B*	1	21	1.38	19	1.3	2	1
113 *D*	1	31	1.6645			10	1.18
108	7	60	1.37			14	1.24

The seed weights from individual heads show that the dark purple seeds are the heaviest. The yellow seeds of one head may weigh more than the purple seeds of another head, but within the same head the yellow seeds are always the lighter in weight. It also holds true for the individual plant that the purple seed are always heavier than the yellow.

From this study of kernel weights and that of color already presented, we see that each head shows a distinct individuality, differing slightly from other heads on the same plant. Comparing the seed weights and seed color of one plant with those of another plant, we find even greater differences between the individual plants.

Determination of the Specific Density of Purple and Yellow Seed.

The specific gravity of the seed was determined by means of the picnometer. For each determination one hundred dark purple or one hundred yellow seeds, representative of the two extremes of color, were taken.

Table X.—*Specific Gravity of Purple and Yellow Seed.*

Source of Seed.	Purple Seed.		Yellow Seed.	
	Wt. 100 Seed.	Sp. Gr.	Wt. 100 Seed.	Sp. Gr.
	Grams.		*Grams.*	
Plot 308 W.....	.1459	1.2777	.1355	1.2419
	.1395	1.2798	.1336	1.2416
Plot 302 W.....	.1485	1.2606	.1317	1.2206
	.1486	1.2561	.1371	1.2260

The above results indicate that the purple seed have a slightly higher specific gravity than the yellow seed.

Comparison of the Moisture, Nitrogen, and Phosphorus Content of Purple and Yellow Seed.

Snyder,[15] in analyses of dark and light seed from four different kinds of clover and from alfalfa, finds that the dark seed have a higher protein content.

Since the purple and yellow seed differ in weight and specific density, there is reason to believe that they might also differ in composition.

[15] Snyder, H., Forage Clops of High, Medium, and Low Protein Content. Minn. Exp. Sta. Bul. 101.

TABLE XI.—*Moisture and Nitrogen Content of Purple and Yellow Seed.*

Source.	Sample No.	Moisture.		Nitrogen.		Nitrogen per Seed.	
		Purple Seed.	Yellow Seed.	Purple Seed.	Yellow Seed.	Purple Seed.	Yellow Seed.
		Percent.	*Percent.*	*Percent.*	*Percent.*	*Mg.*	*Mg.*
P302 W	1–2	8.26	9.01	5.8307	6.0000	0.0765	0.0727
302 W	3–4	8.57	9.14	5.8289	6.0146	0.0766	0.0728
310 E	5–6	8.25	7.99	5.8420	6.0117	0.0824	0.0772
310 E	7–8	8.23	7.91	5.8563	5.9700	0.0826	0.0766
308 W	9–10	9.56	9.15	5.7234	5.8610	0.0732	0.0728
Average		8.57	8.64	5.8162	5.9714	0.0782	0.0744

Table XI indicates that on the basis of weight the yellow seed contain slightly more nitrogen than the purple. Under a previous topic it was shown that purple seed are much heavier than yellow seed. Therefore, in order to find the nitrogen content of individual seeds the number of seed in the sample was determined and the amount of nitrogen found was divided between them. The purple were found to be richer in nitrogen than the yellow seed.

In the determination of ash and phosphorus, two lots of 2,400 purple and 2,400 yellow seeds were separated from bulk sample from Plot No. 308W. The results are shown in Table XII.

TABLE XII.—*Ash and Phosphorus Content of Purple and Yellow Seed.*

No. of Seed.	Color of Seed.	Weight of Seed.	Moisture.	Ash.		Phosphorus.	
		Grams	*Percent.*	*Gr.*	*Percent.*	*Gr.*	*Percent.*
2,400	Purple	3.4065	8.69	0.1246	4.107	19.00	6.29
2,400	Yellow	3.2084	9.04	0.1186	4.143	18.20	6.35

What was true for the nitrogen is also found to be true for the ash and phosphorus, namely, that the yellow seed have a higher percentage of ash and phosphorus, but when individual seeds are considered the purple are found to contain more than the yellow.

LOCATION OF COLORING MATTER IN PURPLE SEED AND THE EFFECT OF DIFFERENT SOLVENTS.

It has been found by Pammel[16] that the coloring of the clover seed is located in the palisade cells. It does not seem to be deposited in these cells until the seed hardens.

In carrying out a determination of the effects of various solvents

[16] Pammel, L. H., Anatomical characters of the seeds of Leguminosae. Trans. Acad. of Sci. of St. Louis 9: 97.

upon the coloring matter in the clover seed, 25 seed were placed in a test tube and 8 or 10 drops of the liquid were added. The coloring material of the purple seed was found to be soluble in cold and hot water and fairly soluble in acids and alkalies. It was insoluble in alcohol, ether, and carbon bisulfid. In a water solution the pigment is colorless, but in the presence of hydrochloric acid and sulfuric acid it gives to the solution a reddish tinge.

Study of Plants Produced from Purple and from Yellow Seed.

For the purpose of studying plants from purple and yellow seed a series of eleven pots were planted in the greenhouse. Nine of the pots were planted with seed from individual plants. Thus the purple and yellow seed of each pot had the same maternal parent. The planting was done during the last ten days of February. The seed was germinated and the sprouted seed picked out and planted. Notes taken on the two sets of plants in each pot for the first four weeks indicate that the plants from purple seed were slightly ahead of those from yellow seed in number of leaves. The plants were cut on the thirtieth of May and weighed.

Table XIII.—*Green Weight of Plants from Purple and from Yellow Seed.*

Plot No.	Source of Seed.	Purple.		Yellow.	
		Total Weight of 5 Plants.	Av. Weight per Plant.	Total Weight of 5 Plants.	Av. Weight per Plant.
		Grams.	*Grams.*	*Grams.*	*Grams.*
1	308 W	67.15	13.48	55.59	11.2
2	302	92.64	18.53	78.6	15.72
3	107 *A*	85.93	17.18	46.5	11.63
4	209 *B*	76.4	15.28	75.62	15.12
5	107 *B*	67.69	13.34	58.16	11.12
6	209 *D*	76.23	15.24	42.55	10.64
7	113 *A*	91.41	18.28	61.61	12.32
8	113 *A*	64.93	12.98	73.02	12.6
9	113 *B*	56.84	14.21	54.04	18.01
10	108 *C*	52.55	17.51	62.43	12.48
11	107 *A*	34.89	8.72	48.21	9.64

These results show a considerable variation in weight of individual plants, but an average indicates that the plants from purple seed are heavier than those from yellow seed.

Summary and Conclusions.

1. The greatest proportion of dark colored seed are located in the lower part of the head. The seeds in the lower part of the head are as a rule heavier than those in the upper part. There is no inheritance of color as a definite character.

2. An abundance of available plant food in the soil increases the proportion of purple seed by increasing maturity. Phosphorus seems to be the principal element in this influence.

3. Purple seed have germinated slightly better than the yellow.

4. The purple seed are heavier than the yellow.

5. The purple seed have a higher specific density than the yellow.

6. The yellow seed show a higher percentage of nitrogen, ash, and phosphorus than the purple seed, but with individual seeds the purple show a higher total content of these constituents.

7. The coloring matter of purple seed is located in the outside row of cells. It is soluble in water and partially soluble in acids and alkalies, but insoluble in alcohol. With hydrochloric and sulfuric acids it gives the solution a reddish color.

8. The plants from purple seed tend to be heavier than those from yellow seed.

The results of this investigation agree uniformly in indicating that, to a great extent, the color of clover seed is a result of maturity. In the process of blossoming the first flowers are put out close to the base of the head. Thus the seed in the lower part has the longest time to develop and becomes most fully mature. It is, therefore, of a darker color, heavier in weight and contains a greater proportion of nutrients.

OSMOSIS IN SOILS: SOILS ACT AS SEMI-PERMEABLE MEMBRANES.

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Presented at the Lansing Meeting, July, 1912.

It is usually stated that the water in the soil is subject to three types of movement, namely, gravitational, capillary and thermal. The experiments described below go to show that soil water is subject to a fourth type of movement, namely, an osmotic movement.

These experiments show for the first time: (1) that soil acts as a semi-permeable membrane; (2) that water is moved through the soil by osmotic pressure.

Before describing the experiments it may be well, for the sake of clearness, to review briefly the epoch-making work of Pfeffer, Van't Hoff and Arrhenius.

In 1877 W. Pfeffer[1] measured the osmotic pressure of various solutions, and showed: (1) that with dilute solutions of the same substance the osmotic pressure is directly proportional to the concentration of the solution; (2) that for a given solution the osmotic pressure increases with the temperature.

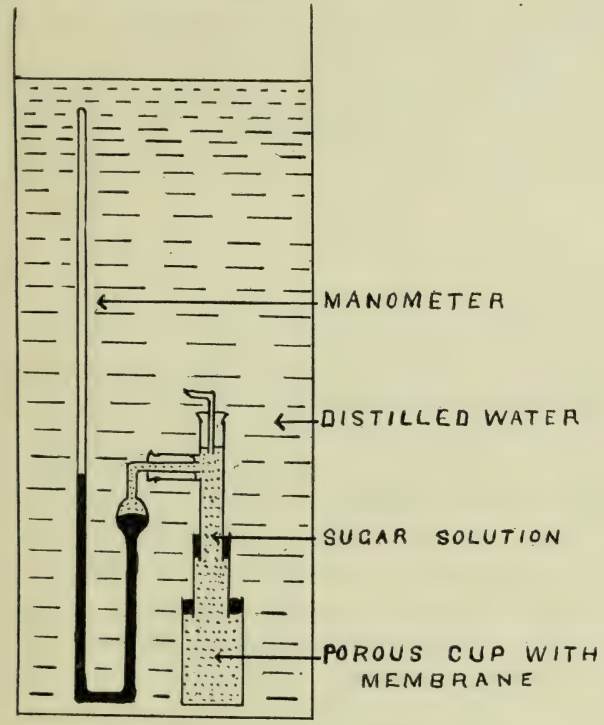

FIG. 4.—Pfeffer's apparatus.

Pfeffer used the apparatus illustrated in Fig. 4. The semi-permeable membrane was a precipitate of copper ferrocyanide deposited within the walls of an unglazed porcelain cup. The osmotic pressure was measured by means of a closed-arm manometer.

With cane sugar solutions ranging in concentration from 1 to 6 percent, he obtained the following results at 14° C.

TABLE I.—*Showing Relation of Osmotic Pressure to the Concentration of the Solution.*

Concentration, percent.	Osmotic Pressure, cm.	Pressure / Concentration.
1	53.5	53.5
2	101.6	50.8
4	208.2	52
6	307.5	51.2

[1] Osmotische Untersuchungen, Leipzig, 1877.

The figures obtained for $\frac{\text{pressure}}{\text{concentration}}$ are nearly constant, which goes to show that the osmotic pressure varies directly as the concentration of the solution.

Pfeffer measured the osmotic pressure of given solutions at different temperatures. The results with a 1 percent cane sugar solution were as follows:

TABLE II.—*Showing Increase of Osmotic Pressure with Increase of Temperature.*

Temperature, °C.	Osmotic Pressure, cm.
6.8	50.5
13.2	52.1
14.2	53.1
22	54.8
36	56.7

These results show that the osmotic pressure of the solution increases with increase of temperature.

In 1887 Van't Hoff[2] reviewed Pfeffer's results, and pointed out the remarkable parallelism between osmotic pressure and gas pressure.

He showed from Pfeffer's results that: (1) At a given temperature, the osmotic pressure of a sugar solution is equal to the gas pressure of a gas which has the same number of molecules in a given volume as there are sugar molecules in the same volume; (2) the osmotic pressure and gas pressure change at the same rate for equal changes of temperature, namely 1/273 of the pressure at 0° C. for each change of 1° C.

Van't Hoff pointed out, moreover, that there are many substances such as acids, bases and salts which give higher osmotic pressure than should be expected from the relations stated above.

To explain these exceptions, Arrhenius[3] in 1887 brought forward the theory of electrolytic dissociation which had been previously stated by Clausius.[4] This theory states that acids, bases and salts in aqueous solution are more or less dissociated into positively and negatively charged particles or ions. Arrhenius assumed that each ion has the same effect as a molecule in producing osmotic pressure, and that the increase in the number of particles by dissociation accounts for the increase in osmotic pressure.

[2] Ztschr. Phys. Chem., 1: 481, 1887.
[3] Ztschr. Phys. Chem., 1: 631, 1887.
[4] Pogg. Ann., 101: 338, 1857.

Arrhenius further pointed out that the percentage of the molecules dissociated could be determined by measurements of the electrical conductivity, and of the lowering of the freezing point of the solution.

Experiments.

In introducing the experiments, I may say that in studying the movement of moisture in soils, I was gradually led to the conclusion, that in producing the movement of moisture in soils, there must be an agency at work more powerful than either surface tension or heat. In considering what this agency might be, I was led to the following theory.

Theory that Soils Act as Semi-permeable Membranes.

It is possible that: (1) soils act as semi-permeable membranes; (2) the greater the depth of the soil the greater its efficiency as a semi-permeable membrane, up to the point at which it becomes a perfect semi-permeable membrane; (3) a soil solution moves through the soil by osmotic pressure from points where the solution is less concentrated to points where it is more concentrated.

To test the validity of this theory I made the experiments described below.

Modification of Pfeffer's Experiment.

Object.—(1) To determine whether a soil acts as a semi-permeable membrane, by making observations on the rate of osmotic flow of water through the soil, if any; (2) to observe the effect, if any, of change of temperature upon the rate of osmotic flow.

The apparatus used is illustrated in Fig. 5. The tube *A* was 1.1 cm. inside diameter and 15 cm. long. The lower end was closed with one layer of cotton cloth covered with brass wire gauze 40 mesh to the inch. The upper end of the tube was fitted with a rubber stopper in which was inserted the bent tube *B*. The bent tube *B* was approximately 1.5 mm. inside diameter. Water, sugar solution and potassium sulphate solution rose in this tube 1.3 cm. by surface tension.

Four tubes were prepared in this way.

The soil used was a heavy clay subsoil (a physical analysis of this soil appears in the following paper by Lynde and Bates).

The air-dried subsoil was allowed to stand in water for one week, and was then distintegrated and sterilized by boiling. The four tubes *A* were sterilized and filled with the hot mixture of subsoil and water. They were placed at once in the centrifuge and the cups of the cen-

trifuge were filled with boiling water to the level of the liquid in the tubes. The centrifuge was then run at top speed for 15 minutes. The middle of each soil column, when settled, was 25 centimeters from the center of the axis of the centrifuge, and the centrifuge made 1,300 revolutions per minute.

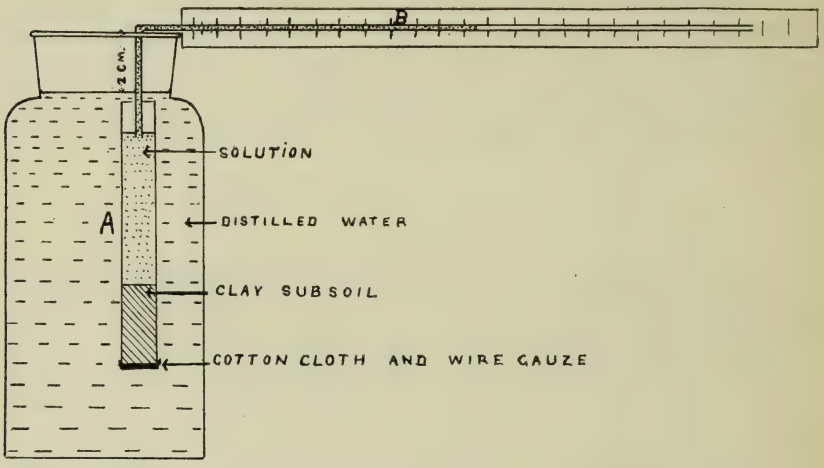

FIG. 5.—Modification of Pfeffer's apparatus. Clay subsoil acts as the semi-permeable membrane.

The solutions used were 10 percent sugar solution and 10 percent potassium sulphate solution. The sugar solution was made by dissolving 100 grams of sugar in 1,000 c.c. of solution. The potassium sulphate solution was made by dissolving 100 grams of potassium sulphate in 1,000 c.c. of solution. Both solutions were sterilized by boiling for one half hour.

As soon as the soils were settled, the liquid above them was emptied out and the tubes were filled with hot sugar solution or hot potassium sulphate solution. The tubes were then fitted with the rubber stoppers and bent tubes *B*, which had been sterilized. The tubes were then washed on the outside and placed in wide-mouth bottles. The bottles were filled with distilled water to a level 2 centimeters below the lower side of the horizontal tube. The tops of the bottles were covered with paper, fastened around the neck with rubber bands. A centimeter scale was placed under each horizontal tube to measure the osmotic flow, if any. The tubes were numbered 1, 2, 3, and 4. 1 and 2 were filled with sugar solution, 3 and 4 with potassium sulphate solution. The results were as follows:

TABLE III.—*Showing Osmotic Flow of Water Through Clay Subsoil.*

Date.	Sugar Solution.		KSO_4 Solution.		Temperature.
	Tube 1.	Tube 2.	Tube 3.	Tube 4.	
Start May 29, 1911.....	*Scale Readings. — Centimeters.*				
May 29, 9.30 a.m.....	26	26.8	23.3	28.5	24.5° C.
30, 9.30 a.m.....	26.2	27.25	22.2	28.7	21.5° C.
31, 11.00 a.m.....	26.5	27.65	21.75	29.25	21°
June 1, 9.30 a.m.....	26.8	27.95	21.7	29.8	20.3°
2, 9.00 a.m.....	27.1	28.15	21.75	30.35	18.5°
2, 9.00 a.m.....	Moved the tubes to the incubator room. This necessitated a change in the position of the scales. Allowed tubes to stand until 5 p.m. before making readings.				
June 2, 5.00 p.m.....	27.52	28.55	21.76	28.62	24.2°
3, 5.40 p.m.....	27.83	28.83	21.68	29.7	24.4°
				7.02[5]	
4, 4.30 p.m.....	28.1	29.1	22.3	8.05	25° C.
5, ——	——	——	——	——	——
6, 10.00 a.m.....	28.5	29.4	24	11.55	24° C.
6, 5.15 p.m.....	28.6	29.4	24.3	12	24.5° C.
7, 4.45 p.m.....	29.4	29.65	25.5	14	24° C.
8, 7.15 p.m.....	31.6	31.3	27.2	16.3	25° C.

These results are represented graphically in figure 6.

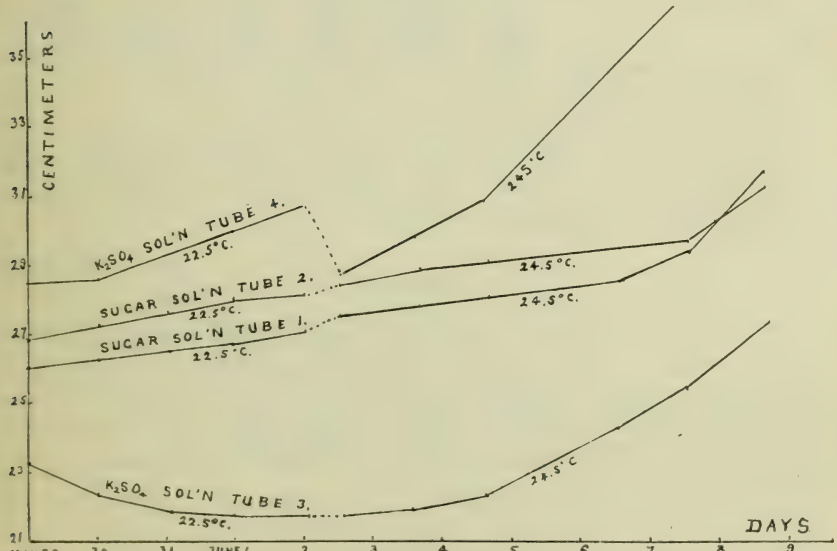

FIG. 6.—Graphs showing the movement of the solution in the tubes *B*.

Conclusions.—These results indicate: (1) that clay subsoil acts as a semi-permeable membrane; (2) that water moves through clay sub-

[5] Liquid reached end of horizontal tube; emptied the tube and started it again at 5.40 p.m., June 3.

soil towards a solution; (3) that the rate at which the water moves increases with the temperature.

It will be noticed that in tube 3 the liquid fell back for the first six days and then moved forward rapidly. It seems likely that in all cases there are two movements—the solution moving out of the tube by gravity, and the water moving towards the solution by osmotic pressure. If the osmotic movement of the water towards the solution is more rapid than the movement of the solution out of the tube, the liquid in the horizontal tube moves forward; if not, it moves back. It would seem that, in the case of tube 3, the movement of the solution out of the tube was the more rapid in the beginning, but that when the temperature was raised the osmotic movement of the water became the more rapid.

FURTHER STUDIES IN THE OSMOSIS OF SOILS.

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Macdonald College, Province of Quebec, Canada.

Presented at the Lansing Meeting, July, 1912.

The experiments outlined in the paper by the senior author were made in the spring of 1911. This spring Mr. Bates joined me and we made the following experiments.

Experiments.

The object of the experiments was: (1) To determine again whether soil acts as a semi-permeable membrane; (2) to determine whether its efficiency as a semi-permeable membrane varies with the depth of soil column; (3) to measure the total osmotic pressure obtained in each case; (4) to find the influence of change of temperature upon the total osmotic pressure obtained in each case.

Apparatus.

The apparatus used is illustrated in Fig. 7. Six tubes were prepared as follows: Each of the tubes *A*, 1.1 cm. inside and 15 cm. long, was covered at the lower end with one layer of cotton cloth. Each tube was fitted with a rubber stopper in which was inserted a glass tube between 1 and 2 mm. inside diameter.

The tubes were numbered 1, 2, 3, 4, 5 and 6. A definite weight of

clay subsoil was placed in each tube. In tubes 1 and 2, 6 grams; in tubes 3 and 4, 4 grams; in tubes 5 and 6, 2 grams.

The soil was prepared as follows: The quantity of soil to be used was weighed out in air-dry condition. It was then placed in distilled

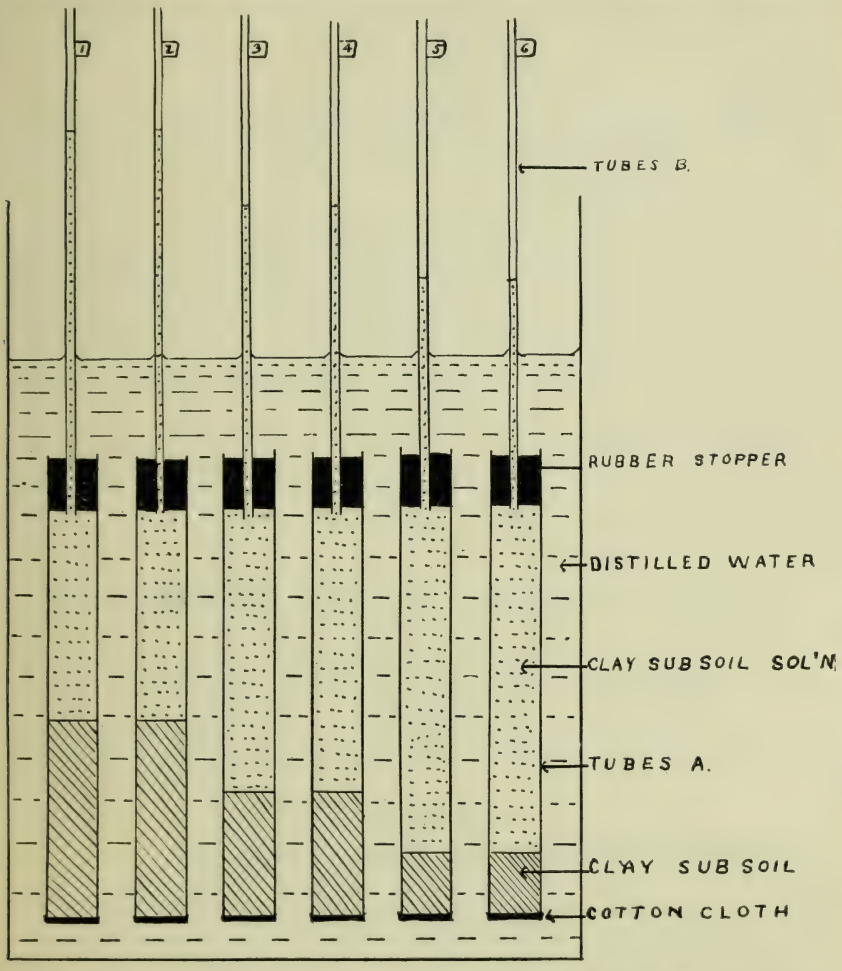

FIG. 7.—Modification of Pfeffer's experiment. The semi-permeable membranes are 6, 4 and 2 grams of clay subsoil, respectively. The solution is that formed by boiling clay subsoil in distilled water.

water in a test tube and allowed to stand over night. In the morning the test tubes were placed in water and the water was boiled for three hours. In the meantime the tubes *A*, the rubber stoppers and the tubes *B* were sterilized in boiling water. The hot mixture of soil and

water was poured into the tubes *A*, and the soils were settled in the centrifuge for 30 minutes at top speed, as described in the preceding paper.

At the end of 30 minutes the rubber stoppers and tubes *B* were inserted in the tubes *A*, and the tubes were placed in distilled water.

The Solutions.

In each case the solution was a clay subsoil solution, namely, the water with which each portion of clay subsoil was mixed and heated. This liquid remained above the soil when the soil was settled, and served as the solution.

In adjusting the rubber stoppers and tubes *B*, the level of the liquid in the tubes *B* was made about 3 centimeters above the top of the rubber stoppers, and the level of the distilled water in the larger vessel was raised above the level of the solution in the tubes *B*. The height to which the solution rose in each tube *B* by surface tension had been measured previously. They are as follows:

Table I.—*Showing Height to Which Water Rose in Tubes by Surface Tension Alone.*

Tube.	1	2	3	4	5	6
Height in cms.....	1.6	1.25	1.1	1.7	1.45	1.35

The length of soil column in each tube *A* after being settled was as follows:

Table II.—*Showing Length of Soil Column in Each Tube.*

Tube.	1	2	3	4	5	6
Length of soil column in cms.....	5.4	5.4	3.6	3.6	1.8	1.8

Results.

The tubes were started on May 1, 1912, at 11.30 a.m.

Table III.—*Showing Osmotic Rise of Moisture in Tubes.*

Date.	May 4	5	6	7	8	9	10	11	12
Time.	9.45 a. m.	9	9.30	8.45	9	8.45	9	9	9
Temp.	19.6° C.	19° C.	18.6°	18.2°	19.2°	19.2°	18.6°	18.8°	19.6°
Tube No.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
1	3	3.3	3.5	3.6	3.9	4	4.1	4.2	4.3
2	2.3	2.4	2.7	2.8	3	3.1	3.1	3.2	3.3
3	1.8	1.8	2.1	2.1	2.2	2.3	2.3	2.4	2.5
4	2.4	2.4	2.6	2.6	2.7	2.6	2.6	2.6	2.6
5	2.7	2.4	2.5	2.3	2.2	2	2.1	2.2	2.2
6	2.3	2.1	2	1.9	1.9	1.9	2	1.9	2.1

TABLE III.—*Continued.*

Date.	May 13.	14	15	16	17	18	19	20	21
Time.	9 a. m.	9	9	9	9	9	9	9	9
Temp.	20°	14.8°	15.2°	16.2°	16.5°	16° C.	16.8°	16.3°	13.8°
Tube No.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
1	4.5	4.2	4.3	4.8	4.8	4.9	5.1	5.1	5.1
2	3.4	3.2	3.3	3.7	3.9	3.7	3.9	3.9	3.8
3	2.6	2.4	2.5	2.8	2.8	2.9	3	3	3.1
4	2.7	2.3	2.6	2.8	2.9	2.8	2.8	2.9	2.9
5	2.3	2.1	2.1	2.2	2.2	2.1	2.2	2.1	2.1
6	2.2	1.8	1.7	2.1	2.1	2	2.1	2	2.1

TABLE III.—*Continued.*

Date.	May 22.	23	Moved to incubator, 9 a. m. May 23	24	25	26	27	28	29	30	31
Time.	9	9		9	9	9	9	9	9	9	9
Temp.	16.5°	16.7°		35.8°	35.4°	36.8°	37.1°	37.4°	37.3°	36.1°	35.7°
Tube	*Cm.*	*Cm.*		*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
1	5.1	5.2		5.8	5.5	5.7	5.9	6.2	5.9	5.9	5.9
2	3.9	4		4.5	4.7	5	5.2	5.4	5.4	5.4	5.6
3	3	3.1		3.6	4	4.4	4.8	4.9	5	5.2	5.3
4	2.9	2.9		5.3	5.2	5.6	5.7	5.9	5.8	5.6	5.6
5	2.1	1.9		2.7	2.6	3	3.1	3.3	3	3	3
6	2.1	1.9		2.6	2.6	2.7	2.9	3	2.9	2.8	2.8

These results show:

1. That clay subsoil acts as a semi-permeable membrane.
2. That water moves through clay subsoil towards a solution.
3. That the greater the depth of the column of subsoil the greater its efficiency as a semi-permeable membrane.
4. That the total pressure increases with the increase of temperature.

ANALYSIS OF RESULTS.

If we take the greatest height to which the solution rose in one tube containing 6 grams of soil, in one containing 4 grams of soil, and in one containing 2 grams of soil, the heights are roughly proportional to the depths of the soil column. Before the apparatus was placed in the incubator the average temperature was 16.7° C. In the incubator it was 36.5° C.

The length of soil columns is 5.4, 3.6, and 1.8 centimeters, respectively. The heights due to osmotic pressure are 3.6, 2.0, and 1.25 centimeters, respectively. That is, the efficiency of the soil column as a semi-permeable membrane is roughly proportional to the depth of the column.

TABLE IV.—*Showing Ratio of Osmotic Rise at 16.7° C. to the Depth of Soil Column.*

	Tube 1.	Tube 4.	Tube 5
Weight of soil in tubes, in grams	6	4	2
Depth of soil column in cms.	5.4	3.6	1.8
Height the solution rose at 16.7° C., cms.	5.2	3.1	2.7
Height the solution rose due to surface tension, alone cms.	1.6	1.1	1.45
The difference equals height the solution rose due to osmotic pressure	3.6	2	1.25

In the incubator the greatest heights were as follows:

TABLE V.—*Showing Ratio of Osmotic Rise at 36.5° C. to the Depth of Soil Column.*

	Tube 1.	Tube 3.	Tube 5.
Weight of soil in tubes, in grams	6	4	2
Depth of soil column, in cms.	5.4	3.6	1.8
Height the solution rose at 36.5° C.	6.2	5.9	3.3
Height the solution rose due to surface tension alone, cms.	1.6	1.7	1.45
The difference equals the height the solution rose due to osmotic pressure	4.6	4.2	1.85

In this case the temperature is higher and the pressures developed are greater than they were in the same tubes at the lower temperature.

Here again the greater the length of the soil column, the greater its efficiency as a semi-permeable membrane, but the proportion is not so close as it is at the lower temperature.

ELECTRICAL RESISTANCE OF THE SOIL SOLUTIONS.

We measured the electrical resistance of the soil solutions at 16.7° C. and at 36.5° C. and at the same time the resistance of a .02 N. KCl solution at 16.7° C.

These measurements enabled us to obtain an idea of:

1. The total osmotic pressure which the solution should develop if the soil column were a perfect semi-permeable membrane.

2. The percent efficiency of the soil column as a semi-permeable membrane.

3. The depth of soil column which should act as a perfect semi-permeable membrane.

The electrical resistances of the solutions were as follows:

TABLE VI.—*Showing Comparison of Electrical Resistance of Soil Solutions to that of .02 N. KCl Solution.*

Solution in	At 36.5 Per Cent.	At 16.7 Per Cent
Tube 1	52 ohms	75 ohms
Tube 2	47 ohms	71 ohms
Tube 3	51 ohms	75 ohms
Tube 4	54 ohms	77 ohms
Tube 5	57 ohms	81 ohms
Tube 6	56.5 ohms	81 ohms

.02 N. potassium chloride solution at 16.7—11.5 ohms.

The molecular lowering of the freezing point of a KCl solution containing .02 gram molecules per liter is 3.58° C. The molecular lowering of the freezing point of a dextrose solution containing .0198 gram molecules per liter is 1.84° C.

The abnormal effect of KCl upon the freezing point is due to the fact that the KCl is dissociated in solution. A KCl solution containing .02 gram molecules per liter has the same effect as a dextrose solution containing

$$.0198 \times \frac{3.58}{1.84} = .038 \text{ gram molecules per liter.}$$

Note.—It must be noted here that we determined the resistance of a .02 N. KCl solution, that is, of a solution in which .02 gram molecules of KCl are dissolved in 1,000 c.c. of solution, whereas the molecular lowering of the freezing point given above was determined for a solution containing .02 gram molecules of KCl in 1,000 c.c. of water. This introduces a slight error. But an assumption which we make later, namely, that the salts in the soil solution are dissociated to the same extent as the .02 N. solution of KCl, probably introduces a greater error. We therefore cannot claim that the results of these calculations are more than an approximation.

Since the freezing point lowering and the osmotic pressure of a solution are both proportional to the total number of particles (molecules and ions) in a given volume of the solution, a .02 N. KCl solution produces the same osmotic pressure as a dextrose solution containing .038 gram molecules per liter.

THE EFFICIENCY OF THE SOIL COLUMNS AS SEMI-PERMEABLE MEMBRANES.

One gram molecule of dextrose dissolved in 22.4 liters of water at 0° C. produces an osmotic pressure of 1 atmosphere or 1,033.6 grams per square centimeter, therefore .038 gram molecules in 1 liter at 16.7° C. produces an osmotic pressure of

$$\frac{1{,}033.6 \times .038 \times 22.4 \times 289.7}{273} = 933.6 \text{ grams per sq. cm.}$$

This is the pressure that should be produced at 16.7° C. by .038 gram molecules of sugar in 1 liter of water or by a .02 N. solution of KCl, if the semi-permeable membrane were perfect.

Let us assume that the salts in the soil solutions are dissociated to the same extent that the .02 N. KCl solution is. We can then calculate from their electrical resistances the osmotic pressure that these solutions should develop with a perfect semi-permeable membrane, and then the efficiency of the soil columns as semi-permeable membranes.

Referring to Tables V and VI in tube 1 at 16.7°, the resistance of the solution is 75 ohms and the osmotic pressure is 3.6 grams per sq. cm. The resistance of the .02 N. KCl solution is 11.5 ohms at 16.7° C.

The soil solution in tube 1 should under the same conditions develop an osmotic pressure of

$$933.6 \times \frac{11.5}{75} = 143.1 \text{ grams per sq. cm.}$$

With the soil column acting as a semi-permeable membrane, the solution develops a pressure of 3.6 grams per square centimeter. Therefore, the soil column, 5.4 cm. long, has an efficiency as a semi-permeable membrane of

$$\frac{3.6 \times 100}{143.11} = 2.5 \text{ percent.}$$

Similar calculations for the other soil columns give the following results:

TABLE VII.—*Showing Relation of Depth of Soil Column to Its Efficiency as a Semi-permeable Membrane.*

	Tube 1.	Tube 3.	Tube 5.
Length of soil column, cm.	5.4	3.6	1.8
Resistance of soil solution at 16.7° C., ohms.	75	75	81
Osmotic pressure with a perfect semipermeable membrane, grams per sq. cm.	143.1	143.1	120.2
Osmotic pressure observed, grams per sq. cm.	3.6	2	1.25
Percent efficiency of the soil column as a semipermeable membrane.	2.5	1.4	1.0

DEPTH OF SOIL COLUMN WHICH WOULD BE A PERFECT SEMI-PERMEABLE MEMBRANE.

If we assume that the efficiency of a soil column as a semi-permeable membrane is directly proportional to its depth, then the depth of soil

column required in each tube to produce a perfect semi-permeable membrane is as follows:

In tube 1, a soil column 5.4 cm. deep has an efficiency of 2.5 percent, therefore a soil column

$$5.4 \times \frac{100}{2.5} = 216 \text{ cm. deep}$$

would be a perfect semi-permeable membrane.

In tube 3, a soil column 3.6 cm. deep has an efficiency of 1.4 percent, therefore a soil column

$$3.6 \times \frac{100}{1.4} = 257 \text{ cm. long}$$

would be a perfect semi-permeable membrane.

In tube 5, a soil column 1.8 cm. long has an efficiency of 1 percent, therefore a soil column

$$\frac{1.8 \times 100}{1} = 180 \text{ cm. long}$$

would be a perfect semi-permeable membrane.

Experiment Repeated.

The soil solutions used above were thrown away after their electrical resistances had been determined. The tubes were then scalded on the outside with boiling water. They were then filled with boiling distilled water, placed in distilled water and started again. The distilled water in the tubes was left to form a new clay subsoil solution in each tube.

They were started on May 31, 1912, and allowed to run until July 6 at room temperature, average 25° C. The highest pressures developed were as follows:

Table VIII.—*Showing Relation of Depth of Soil Column to Its Efficiency as a Semi-permeable Membrane. Second Experiment.*

	Tube 1.	Tube 2.	Tube 3.	Tube 4.	Tube 5.	Tube 6.
Weight of soil, grams	6	6	4	4	2	2
Length of soil column, cm.	5.4	5.4	3.6	3.6	1.8	1.8
Total height, cm.	5.4	4.8	4.2	4.4	2.4	4.5
Height due to surface tension	1.6	1.25	1.1	1.7	1.45	1.35
Height due to osmotic pressure	3.8	3.55	3.1	2.7	.95	1.15

It will be seen that the pressures developed are in the same order as in the previous experiment, but a little higher in each case, because the temperature ranged somewhat higher.

Experiment with Twelve Grams of Subsoil in Each Tube.

On May 13, 1912, we started two tubes, each containing 12 grams of clay subsoil, prepared and settled as in the experiment above. The soil column in each was 10.8 cm. long, or twice as long as those in tubes 1 and 2 above. The solution was a clay subsoil solution as above. The solution in the tubes was still rising on July 7. The measurements on that date were as follows:

Table IX.—*Showing Comparative Rise of Moisture Through Soil Columns, Due to Surface Tension and to Osmotic Pressure.*

	Tube 1.	Tube 2.
Weight of soil, grams	12	12
Length of soil columns, cm	10.8	10.8
Total height, cm	6.9	7.2
Height due to surface tension	1.7	1.6
Height due to osmotic pressure	5.2	5.6

The solution is still rising, but it has already gone far enough to give further evidence that the efficiency of a soil as a semi-permeable membrane increases with the depth.

Physical Analysis of Clay Subsoil.

The physical analysis of the clay subsoil used in all the experiments above gave the following results:

	Percent.
Sand, 2 mm.–1 mm.	1.48
Sand, 1 mm.–.5 mm.	1.05
Sand, .5 mm. or less	7.96
Silt	50.42
Clay	36.28
Organic matter	2.81
	100

Experiments with Other Subsoils.

On June 3, 1912, we started experiments with three subsoils taken from different parts of the Macdonald College farm. The physical analyses of the soils gave the following results:

Table X.—*Showing Physical Analyses of Other Soils Used.*

	Soil 1.	Soil 2.	Soil 3.
	Percent.	*Percent.*	*Percent.*
Sand over 1 mm.	1.7	.5	.6
Sand 1–.5 mm.	2.2	4.1	4.9
Sand under .5 mm.	40.9	49.1	55.4
Silt	41.3	29.5	23.0
Clay	12.2	15.8	15.0
Loss	1.7	1.0	1.1
Organic matter, separate determination	6.08	4.2	2.8

Duplicate experiments were made with each soil. Each tube contained 6 grams of soil settled as in the experiments above. The soil solution was again the water in which the soil was boiled. The results on July 5 were:

TABLE XI.—*Showing Rise of Moisture in Six Tubes of the Same Soil.*

	Soil 1.		Soil 2.		Soil 3.	
	Tube 1.	Tube 2.	Tube 3.	Tube 4.	Tube 5.	Tube 6.
Total height, cm.....	1.3	1.1	1.3	2.1	1.1	1.3
Height solution rose due to surface tension.....	1.6	1.6	1.6	1.6	1.6	1.6
Height due to osmotic pressure.....	−.3	−.5	−.3	+.5	−.5	−.3

In only one case is there any evidence of osmotic pressure. In tube 4 there is a rise of .5 cm. It will be noticed that in these soils the percentage of sand is high and the percentage of clay low. This may account for the lack of osmotic pressure.

CONCLUSIONS.

These experiments show that for clay subsoil prepared as above the following is true:

1. The soil acts as a semi-permeable membrane.
2. The efficiency of the soil as a semi-permeable membrane increases with the depth.
3. Water moves through the soil towards a solution and develops a certain osmotic pressure.
4. The osmotic pressure developed increases with the temperature.

APPLICATION OF THE THEORY.

The theory as given in the preceding paper states that the soil acts as a semi-permeable membrane; that its efficiency as a semi-permeable membrane increases with its depth; and that moisture moves through it from points of low concentration to points of high concentration.

Our experiments substantiate this theory only for the case of a heavy clay subsoil prepared in a certain way. It remains yet to show that it holds for soils under field conditions.

If we consider the application of the theory to agricultural practice in general, we find that it is suggestive in many ways, as follows:

Tillage.

If we consider the different operations of tillage: ploughing, harrowing, etc. These stir up the soil and permit the air to enter. This

makes the conditions more favorable for the growth of bacteria; the bacteria produce plant food, that is, salts soluble in water; this increases the concentration of the soil solutions in the upper layers of soil. This in turn increases the osmotic pressure of these solutions, and therefore increases the amount of water raised from the lower depths through the subsoil (see Fig. 8).

We see, then, that the theory suggests one of the benefits of tillage.

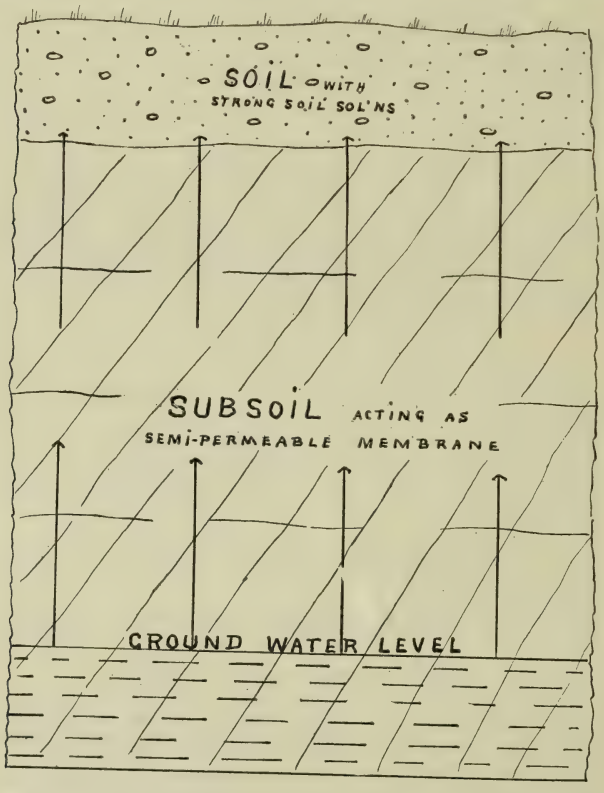

FIG. 8.—Diagram illustrating the movement of water in the soil by osmotic pressure. An increase in the concentration of the soil solutions, brought about in any way, increases the amount of water raised by osmotic pressure. The arrows represent water rising by osmotic pressure.

Drainage.

It is well known that crops on drained land receive more moisture than crops on underdrained land. This may be due to a deeper root system, but it may also be due to the following.

In drained land the water level is lowered to a depth of 3 or 4 feet

below the surface. This permits air to enter to this depth. The conditions then are more favorable to the growth of bacteria, the bacteria produce more soluble salts, which increase the concentration of the soil solutions. The soil solutions in the upper 3 or 4 feet then have a greater osmotic pressure and lift a larger amount of water from below through the subsoil.

We see, then, that the theory offers an explanation of the greater amount of moisture received by plants on drained lands.

Manure.

Experiments made by King[1] show that in land, treated with manure well worked in, the rise of moisture is stronger than in land not so treated. This cannot be due to a greater capillary rise, because manure added to water decreases the surface tension of the water.

Our theory offers an explanation. The manure added to the soil increases the amount of food available for bacteria. The increased number of bacteria produce a larger supply of plant food in the form of soluble salts. This increases the concentration and therefore the osmotic pressure of the soil solutions near the surface. The increased osmotic pressure increases the amount of moisture raised through the subsoil (see Fig. 8).

Mineral Fertilizers.

When mineral fertilizers are added to the land, the concentration of the soil solutions near the surface is increased. This increases the osmotic pressure of these solutions, and, according to our theory, should increase the amount of moisture raised through the subsoil.

This may be one of the beneficial results obtained by adding mineral fertilizers to the land.

It may also explain one of the benefits of adding to the soil fertilizers which are not directly plant foods, such as gypsum and salt.

Increase of Temperature.

If the rise of moisture in soil is all brought about by capillary action, then the supply in summer should be less than that in spring or fall, because the surface tension of water decreases with an increase in temperature. That is, the supply of moisture to plants should be least when they most need it. It is true that the decrease in surface tension is offset to some extent in two ways: by the increase in concentration by evaporation of the solutions near the surface which in-

[1] King, F. H., Wisconsin Station Report, 1893, pp. 167–200.

creases the surface tension, and by the increase in fluidity of the water at higher temperatures.

If, however, the rise of water is due partly to osmotic pressure, the supply of water would be increased by an increase in temperature in a number of ways (see Fig. 8).

1. The increased evaporation would increase the concentration, and therefore the osmotic pressure of the solution near the surface. This would increase the amount of water raised through the subsoil.

2. The increased bacterial action, at higher temperatures, would increase the concentration and osmotic pressure of the soil solutions. This would increase the amount of water raised through the subsoil.

3. With increase of temperature more soluble salts would be dissolved in the soil solution, and their osmotic pressure would thereby be increased. This again would increase the amount of water raised through the subsoil.

4. The osmotic pressure of any solution is increased by an increase of temperature. This would be the case with the soil solution.

We see, then, that the osmotic pressure of the soil solutions near the surface would be increased by an increase of temperature. This would increase the amount of water raised from below through the subsoil. That is, in summer when the plants need more water, they would receive it.

The Soil Mulch.

A soil mulch conserves the moisture in the land for the benefit of the crop. Our theory suggests another way in which the amount of water under the mulch is increased, as follows. Bacteria thrive when there is moisture as well as heat. If the soil is dry the bacteria remain dormant. Under a soil mulch the land is moist and warm. These are the ideal conditions for bacterial growth. Under the mulch then the bacteria produce plant food and increase the osmotic pressure of the soil solutions as described above. This increased osmotic pressure would increase the amount of water raised through the subsoil.

That is, one of the benefits of a soil mulch may be that a greater amount of moisture is raised from below by osmotic pressure.

Dry Farming.

In dry farming it is the practice in some cases to plant a crop every other year, and to maintain a mulch on the land in the off year. The explanation of the benefit of this is that the moisture is held over for the crop the succeeding year.

Our theory suggests that the increased crop the second year may

be due partly to the increase in the osmotic pressure of the soil solutions near the surface due to bacterial action, as explained under soil mulch above.

The explanation of the increase in crop may be that water is drawn from a greater depth in land that has been mulched.

Opens Large Field for Investigation.

The theory then suggests one benefit derived from the ordinary operations of cultivation: tillage, underdrainage, the use of fertilizers, and soil mulching.

It also opens up a large field for investigation in soils, as follows:

1. Do soils other than clay subsoil act as semi-permeable membranes?

2. Does the efficiency of a soil as a semi-permeable membrane depend upon the percentage of clay it contains? If so, how?

3. Do soils under field conditions act as semi-permeable membranes?

4. Does a higher salt content increase the water-holding capacity of soils?

5. Do the operations of tillage: ploughing, harrowing, etc., increase the amount of water raised through the subsoil?

6. Do fertilizers increase the amount of water raised through the subsoil.

7. Does underdrainage increase the amount of water raised through the subsoil?

8. Does a soil mulch increase the amount of water raised through the subsoil?

9. Does the soil mulch used in dry farming one year increase the depth from which water is raised to the plants the next year?

10. Are there substances, other than those at present known, which are not plant foods but which can be used as fertilizers with benefit?

11. In the domain of pure physics it is possible that the experiments described above may throw light upon the action of semi-permeable membranes in general and upon the cause of osmotic pressure.

CARE AND MANAGEMENT OF LAND USED FOR EXPERIMENTS WITH FARM CROPS.

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It is probably safe to say that one of the most difficult problems in the carrying out of field experiments is the care and the management of the land. When a person undertakes to conduct experiments with farm crops in the field, he sooner or later comes in contact with difficulties which are hard to overcome in the ordinary cultivation of the soil. It is doubtful if any experimenter on the American continent has solved some of the questions to the entire satisfaction of himself. I venture to bring this subject before you, not because I consider that I have obtained an ideal method, but rather to open up the question for discussion that others may have an opportunity of presenting their views. In order that the discussion may be directed along fairly definite lines, I shall venture to state in a simple way what is being done at Guelph with a hope that others present at the meeting may also be induced to give simple statements of the methods which they are following. While it is true that no one plan of operation will apply equally well under all conditions and circumstances, we believe that a discussion of this kind will present suggestions which might be of great value, especially for those who have been conducting field experiments for a comparatively short time. In handling the land used for the purpose of experiment with farm crops, such as the testing of varieties, the selection of seed, the depth of planting, the time of planting, the advisability of growing grain singly or in combination, and similar experiments, it is important to know just what is best to be done in regard to underdraining the land, cultivating the soil, the system of rotation, the application of fertilizers and manures, etc. While it is important to conduct definite experiments along each of these lines, it is also absolutely necessary to deal with those same questions in the regular experiments which deal with other problems. It seems to me that there is a great danger of being somewhat careless in connection with some of these operations, and that the results obtained will be reduced in value accordingly. On the other hand, there is a danger of being so impractical that the work is removed beyond the method and the comprehension of the average farmer so

as to lose the value of his sympathy and his appreciation of the experiments. Results of practical field experiments are of but little use unless they appeal to the farmers in such a way that they make use of them in the handling of their own farms.

The facts presented in this paper deal with land which is being used for experimental purposes over a series of years. They do not deal with distinct and separate experiments with fertilizers, with rotations, with perennial crops, such as grasses, alfalfa, etc., which require somewhat different methods of operation.

Underdraining the Land.

One of the first problems which confronts an experimenter after he has selected his land for the purpose of experiment is the extent and the method of underdraining it in such a way as to give the most satisfactory results. In considering this matter a careful study should be made, not only of the land itself, but also of the soil of the district, and of the methods followed by the farmers. Speaking in a general way, I believe it is wise to underdrain in a thorough and systematic manner if a whole or a part of the land to be used for experiment requires it. If this is not done there is danger of obtaining results which are more or less unreliable. In our old experimental grounds at Guelph, which contain about 2,000 plots, the land is underdrained with a considerable amount of thoroughness. In a new section of twenty-five acres which is at present being added to the former area the underdrainage has been carried out in a very systematic and thorough manner, so that every plot in the grounds will have an underdrain running across its center. The high as well as the low land is receiving the same thorough treatment.

Cultivation of the Soil.

In cultivating the soil it has been our aim to give thorough work, but not beyond the practice of our best farmers. I do not think it is wise, for instance, to sow grains in connection with experiments with varieties, methods of seeding, etc., on land which has not been well prepared, nor yet do I think it would be wise to cultivate the land so much that the farmers would consider that the method would be impractical.

Rotation of Crops

One of the most difficult problems in handling land which has been devoted to experiments is to arrange the crops in such a way as to follow a reasonable and a satisfactory rotation. In order to arrange

such a rotation the agricultural conditions of a district have to be carefully studied, and the various requirements of the experiments under way have to be taken into consideration. In order to get the crops to follow each other in such a rotation that all the essential features of a good rotation may be realized, and at the same time so that the rotation will fit in nicely with the experiments and will meet the sanction of the most progressive farmers, is a difficult matter. After carefully considering this question the following rotation was adopted for the greater area of our experiment grounds: *first year,* grain; *second year,* cultivated crops; *third year,* grain; and *fourth year,* pasture. This rotation has given us about the right proportion of land for our experiments with grain and with cultivated crops; it has appealed to our farmers as a reasonable rotation; it has furnished a cleaning crop; and it has supplied a leguminous crop in the pasture. The pasture which is used is produced by sowing in the spring a mixture of oats, Early Amber sorghum, and common red clover. This crop growing over the whole of the land tends to keep it uniform, and at the same time to afford an opportunity to make observations as to whether the crop grows evenly over the whole area. The annual pasture crop is in itself the result of one of our own experiments in which the farmers are deeply interested. We have a rotation which is answering very nicely in meeting the requirements of our own particular work in field experiments.

Manuring the Land.

There was a time in Ontario when some of our practical farmers, knowing that our institution was supported by the government, and believing that we were in possession of a considerable amount of money, seemed to have the impression that the land which we used for the purpose of experiment received an excessive amount of commercial fertilizers. The farmers of Ontario do not as a rule use commercial fertilizers for their general farm crops. We have conducted numerous experiments in the testing of different fertilizers with various kinds of crops, but on the land used for other experiments no commercial fertilizers whatever have been used. We manure the land once every four years with farmyard manure, at the rate of twenty tons per acre, which would be equivalent to about twelve good-sized loads. We take particular pains to have the manure as uniform as possible, and apply it as evenly as we can on the land. The manure is always applied just previous to the growing of the cultivated crops. This system appeals to the farmers as being very reasonable from their standpoint, and as a result they take a much

deeper interest in the results of the experiments than they would if we were treating the land in a manner with which they were largely unfamiliar. This system may be changed at some future time, but at present it seems to be working well and has the approval of our student body and the farmers generally.

The Value of the Coöperation of the Farmers in the Application of the Results of Experiments.

It will be seen that I have strongly emphasized the conducting of experiments in such a way that they will appeal directly to the people for whom they have been conducted. There is not much use in conducting experiments with farm crops unless the farmers have confidence in the results and endeavor to make a practical application of them in connection with their own farming operations. At Guelph we put great emphasis on care and accuracy in our work, and, while we aim to conduct the work in such a way that it would meet the approval of the scientists, we endeavor throughout to keep in very close sympathy with the men who are living on the land throughout the Province of Ontario. That we have been fairly successful in this appears to be shown from the fact that about 25,000 farmers visit the college in the month of June each year, at the time when they can leave their work at home, and examine the various experiments with farm crops which are being conducted on the college grounds. On the various days throughout the month of June most interesting talks and discussions are carried on with these thousands of farmers who have an opportunity of comparing the different crops, of having the work explained, of asking questions regarding the results of previous experiments, etc. In that way the farmers and the officers of the experiment stations come in close contact with each other, the farmers learning the results of the experiments, and the experiment station officers having an opportunity of knowing better the needs of the farmers and those problems in which they are most deeply interested. This close sympathy between the experiment station and the farmer is also shown through the system of coöperative experiments which are conducted throughout Ontario. This work was started in 1886, in which year there were twelve experimenters. In the following year the number increased to sixty, and in the next year to ninety. This number has gradually increased until at present there are upwards of five thousand (5,000) Ontario farmers conducting coöperative experiments on their own farms. These coöperative experiments are all conducted with material, and according to instructions, furnished by the college through the medium of the Ontario Agricul-

tural and Experimental Union. Through these and other agencies the principal farm crops of Ontario have been actually increasing in yields per acre during recent years.

THE IMPROVEMENT OF SMALL GRAINS AT MACDONALD COLLEGE.

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Three systems are employed at Macdonald College in an attempt to maintain the purity, increase the yield and improve the quality of small grains. Head-selection is practiced annually to keep standard varieties free from mixture; the centgener system is used to isolate and multiply promising mother plants; cross-breeding is employed to combine into one individual the desirable qualities existing in two or more pure-line strains of proven worth.

These systems constitute progressive stages in the improvement of small grains. Careful head-selection must precede intelligent centgener tests. Cross-breeding cannot be most advantageously employed unless pure-line strains of proven efficiency are used as foundation stock.

In this paper I shall confine myself to a discussion of our method of employing the centgener system and then deal briefly with some of the results obtained by this means during the past five years.

When the improvement of a given variety is undertaken, a hand selection is made of the most typical heads from the standing plot. During the winter a careful laboratory study is made of the heads and grains and the most typical are used the next spring for planting the foundation beds.

These beds, for convenience of planting and for facilitating a study of the resulting plants, are 100 links by 10 links. Only the most uniform parts of the experimental grounds are used for this purpose. The preparation of the seed bed is largely performed by hand labor. When properly fined and levelled each bed is marked off into squares four inches each way and a single seed is dibbled in at the corner of each square. This distance between plants has been decided upon because, so far as space is concerned, it approximates field conditions

as closely as is consistent with enabling one to make a careful study of each individual plant.

At harvest time the two outer rows in the foundation beds are discarded, as plants so situated have had a decided advantage over those in the center of the plot. If a seed has failed to germinate, or if for any reason a plant has been destroyed, all plants immediately surrounding the blank space are discarded. Likewise all inferior and all mediocre plants are rejected and only those which, from a study of their physical characters, give evidence of making some advance over their fellows, are retained as possible progenitresses of new strains.

In harvesting foundation beds each plant is pulled up separately by the roots and carefully examined. Individuals which give promise of meeting our requirements are taken to the laboratory where a much more careful study of the plant, straw, head and grain is made. Usually a bed of 3,940 plants gives about 150 individuals of sufficient promise to warrant careful laboratory study. From this number not more than ten or twelve individuals, on the average, will measure up to standard requirements. These are threshed separately and the number and weight of the grains to be used in planting the centgener for the next year is determined. This somewhat full information is recorded not only for future reference but also to enable one to plat exactly the area required for next season's planting.

Centgener beds are planted the same as foundation beds, except that two rows of a different grain are planted between centgeners. When these are removed at harvest, and the outer rows on the beds which are also planted with the same kind of grain are removed, the progeny of each mother stands out clearly and so enables one to make a careful comparative study of the different strains. Those centgeners which have not bred true to the characters of the mother plant are discarded; those which have are harvested after full field notes have been taken. During the following winter each centgener is subjected to the same rigorous selection to which its parent was put the preceding year. Those which reach the high standard set for yield and quality are retained and multiplied; all others are discarded without further trial.

After the obviously inferior grains have been discarded, the product of the chosen centgeners is used to sow the multiplying plots. By this time the quantity of seed is sufficiently large to enable us advantageously to seed the plots broadcast. The exercise of great care, however, is still imperative and necessitates sowing, covering, rolling, etc., by hand to avoid mixing. Likewise these multiplying plots, though frequently one hundredth acre in size, are cut with a sickle,

threshed by hand in sacks and cleaned by a blast of air from an electric fan to insure maintaining the highest possible standard of purity in each strain. The product of each multiplying plot is bagged separately and stored in metal seed cabinets in which each drawer has a separate compartment. This reduces to a minimum the danger of loss from mice, and renders mixing impossible. If, at the conclusion of a five years' field test, any of these strains demonstrate their superiority over the parent variety we have in this reserve an absolutely pure supply of seed with which to sow a much larger field plot and thus enable us to make a dissemination of the new strain sooner than would otherwise be possible. Few strains are discarded in the multiplying plots; practically all that are entered are carried forward next year to the larger trials in the general field.

In the field test for new strains the plots are all one hundredth acre in size. Here the new pedigree cultures are subjected to the station's final test. The new strains are sown beside the parent varieties and a five years' test is conducted to determine whether or not improvement has been effected. If sufficient advance in the desired direction has been made to warrant the placing of a new strain in commerce, sufficient land has been set aside to multiply these strains advantageously and so enable us to make an early dissemination of the new strain.

Results of five years' work with the centgener system at Macdonald College are now available. Of the more than 500,000 single plants grown under control as previously described, only the best from the 116,000 planted in the spring of 1907 have thus far been tested side by side with the parent sorts in one hundredth acre plots for two years. From eighteen of our most productive varieties, representing four classes of wheat, three of barley and two of oats, thirty-seven strains have been isolated, which, on an average of the past two years, have yielded from one to five bushels per acre more than parent sorts grown beside them.

It is especially worthy of note that these average increases for two years were not obtained over the original, unselected parent stocks, but were obtained over original stocks which have, for the past five years, been subjected annually to the most careful hand selection of heads in the field and of grain in the laboratory.

Notwithstanding the rigorous selection described, we had under test in the field in 1912 three hundred and twenty-six pure-line strains.

While these results convey some idea of the possibilities in the centgener system, it is not to be inferred that there is no place for other systems of improvement. In the opening paragraph attention was

drawn to the fact that the three system generally employed were, in reality, progressive steps leading up to the accomplishment of a desired result. Realizing this, and believing that results can be most economically obtained only when pure-line foundation stock of known performance is utilized in cross-breeding, the department did not begin the work of crossing until last year when its first pure, tested stocks were available for this purpose.

SEED AN IMPORTANT FACTOR IN THE CONTROL OF COTTON ANTHRACNOSE.

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Presented at the Fifth Annual Meeting, Atlanta, Georgia, November, 1912.

The fungus boll rot of cotton—cotton anthracnose—has been known and studied for twenty-five years. It is just within the past few years, however, that the economic phases of the disease have been receiving serious consideration at the hands of pathologists.

For four years we have been studying this disease at Clemson. During this investigation a number of interesting things have been brought out.

For the benefit of those of you who are not familiar with the disease I have brought along some specimens of diseased bolls and some colored illustrations of the different stages of the disease.

Anthracnose is, of course, primarily a boll disease. Sometimes, however, if conditions are right, it attacks and destroys large quantities of seedlings and thus injures the stand.

Early in our study of anthracnose we found spores and filaments of the fungus on the inside of seed taken from slightly diseased bolls. We also found that mature slightly diseased seed, when germinated or planted in the field, produced diseased plants, i. e., we proved, at least to our own satisfaction, that anthracnose is carried in the seed. The various experiments conducted along this line and the results obtained have been reported in articles published in our Experiment Station Reports for the past three years, so I shall not take up your time with them here.

The thing which I wish to call special attention to at this time is the kind of stalks and bolls from which we get diseased seed. Since

we learned that anthracnose is carried in the seed, we have been conducting experiments relative to the control of the disease by seed selection and, in this connection, have been making an effort to determine just what kind of bolls produce diseased seed. At first we were very much struck with the bolls which have only one or two diseased locks with the other two or three locks open and apparently healthy. From such open, healthy-looking locks in diseased bolls we found all of the seed diseased. During the past two years we have made a careful study of *all kinds* of bolls from diseased stalks. Here we have obtained some interesting results.

Seed from Diseased Stalks.

During the season which has just closed we planted in the field seed from 190 bolls which were taken from diseased stalks last season and were examined under microscope and studied in the laboratory during the winter. Some of the seed from each boll were germinated in the laboratory under sterile conditions and the amount of disease on the seedlings noted. The remainder of the seed were planted in the field the first week in May and from five to ten stalks were grown to maturity from the seed from each boll.

Seed from such of these bolls as appeared free from disease, and which, upon microscopic examination, showed no spores or filaments of the fungus, developed anthracnose when germinated in the laboratory and when planted in the field. On the progeny of such bolls this season 12.7 percent of the cotton was destroyed by the disease. The progeny of other bolls which were mature and open, but which contained slightly discolored lint and otherwise looked suspicious and when examined under microscope showed presence of spores of the fungus, produced an average of 17 percent of diseased bolls this season, while seed from definitely diseased bolls produced stalks on which from 5 percent to 85 percent of the bolls, with an average of 25 percent, were diseased this season. The progeny of healthy-looking bolls taken from diseased stalks in 1910 and planted in the field last year showed 20 percent of the bolls diseased, while the progeny of definitely diseased bolls produced 48 percent.

Seed from Disease-free Stalks.

At the same time stalks, which seemed to be free from disease, were selected from the same progeny rows. The progeny of such stalks have developed no disease. This has proved true with similar experiments for the past three years.

Our experiments then prove pretty conclusively that it is not at all safe to select seed from any kind of boll from a stalk which contains one or more diseased bolls. They prove, on the other hand, that the disease can easily be eliminated by careful selection of seeds from stalks which are free from anthracnose.

Now a great many of our cotton breeders and seedsmen have not paid enough attention to anthracnose. A careful survey of the situation in South Carolina shows that in practically every case where the disease is causing trouble the seeds have been purchased from some breeder or seedsman. Every man who originates a new variety or promotes an old variety of cotton seems to be so anxious to sell seed that he gathers every one he can get without reference to disease.

Let me give you one illustration of this. A gentleman over here at Duluth, Ga., has a variety of cotton which he calls "Half-and-Half"—a selection from the Cook variety. He says he sold seed of this to between 500 and 600 farmers in South Carolina this spring. Every one of those farmers that we have heard from reports more than 30 percent of his cotton destroyed by anthracnose. Some of them say 75 percent of the bolls failed to open and others say their crop is completely destroyed. One acre of this cotton on the Experiment Station farm shows by actual count that 50 percent of the bolls are diseased. Now you can readily see that this man has not only sold 1,000 or 1,500 bushels of diseased seed to South Carolina farmers at $5.00 per bushel, but he has caused them to lose half of the cotton grown from such seed and in addition has infected their farms with a destructive and troublesome disease. We have many reports of cases similar to this. Thousands of bushels of diseased seed are sold to South Carolina farmers every year and these diseased seed invariably produce diseased cotton.

The staple cotton industry is also seriously threatened by anthracnose, and simply because the breeders in the beginning paid too little attention to the disease. A survey made this fall of 3,539 acres on 72 farms shows by actual count that from 2 percent to 30 percent of the cotton in individual fields of Allen Long-staple, Keenan, Webber, Columbia, and Hartsville is diseased. The average percent of rotten bolls in the fields examined was: Keenan, 3 percent; Columbia, 6.6 percent; Hartsville, 6.3 percent; Webber, 9.4 percent. Not a single field of staple cotton has been found entirely free from the disease. Here, again, of course, the breeders are at fault.

We now have a law in South Carolina which makes it unlawful for any one to transport or sell in the state seeds which are diseased. We hope by this means to keep the disease in check and to protect the farmers from the unscrupulous seed promoters.

Since this disease, according to a prominent Georgia experimenter, causes a loss of from seventeen to twenty million dollars to the South every year, it seems that it is time for other states to have similar laws and coöperate with South Carolina in blotting out cotton anthracnose.

THE INTENSITY OF NITRIFICATION IN ARID SOILS.

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(Contribution from the Chemical Laboratory, Utah Experiment Station, Logan, Utah.)

HISTORICAL.

It is a very common conception that nitrification takes place with great intensity in arid soils. Thus Hilgard,[1] in discussing the intensity of nitrification in arid climates, says: "Of the efficacy of nitrification under arid conditions abundant evidence may be found in the state of California. *In the alkali lands* of southern California the nitrates of soda, lime and magnesia are almost universally present; they form at times as much as one fifth and even more of the entire mass of alkali salts, and in one case the total amount in the soil has been found to reach two tons per acre with an average of twelve hundred pounds over ten acres." It should be carefully noted that these accumulations of nitrates occurred in *alkali soils,* together with the other more common alkali salts. But Hilgard evidently assumed that their formation was taking place with great rapidity at the present time.

Colmore,[2] working under Hilgard's direction in 1892, made a study of the distribution of the alkali salts from the center of an alkali spot to the outer edge. Some of the results he obtained are recorded in Table I.

TABLE I.—*Distribution of Salts in an Alkali Spot, Recorded in Pounds Per Acre-foot of Soil.*

Location.	Center.	Eight Feet from Center.	Outer Margin.
Total salts	1,368.	1,942.	827.9
Nitric nitrogen	.67	2.77	.17

It may be noted that the greatest quantity of nitric nitrogen occurs in the eighth foot from the center, together with the greatest quantity of *total alkali salts.* The nitrates are thus seen to be closely asso-

[1] Hilgard, E. W., Soils, p. 68.

[2] Colmore, Charles, California Expt. Sta. Rept., 1892–94: 141.

ciated with the other alkali salts. The nitrates must either have been brought up from lower depths or else the alkali salts must exert a very marked influence in increasing the rate of nitrification. Hilgard evidently assumes the latter conception to be true, for, in discussing these results, he says:[3] "The lowering of the nitrate content at the outer margin is obviously due to the luxuriant vegetation growing adjacent." And elsewhere[4] he also says: ". . . Saltpeter in the form of both potassium and sodium nitrates is common, especially in the black alkali districts, and represents a surplus of the most expensive of fertilizers which the farmer finds it necessary to supply to his soils in order to maintain their productiveness. While it is true that these nitrates are not retained in the soil but pass away in the drainage, their presence testifies to the intensity of the nitrifying process in the soil under the conditions of the local climate."

Recently Headden[5] has found abundant accumulation of nitrates in certain alkali soils of Colorado which he attributes to the fixation of atmospheric nitrogen by bacterial action at the present time. While it is probable that the nitrogen fixed by the microörganisms of the soil is in the form of protein nitrogen, Headden believes that nitrification takes place at the same time, thus also assuming that nitrification takes place rapidly in arid soils, since the amount of nitrates present in the Colorado soils reaches enormous quantities per acre.

There are a number of other examples of nitrate accumulations occurring in arid soils, such as those of Turkestan,[6] India,[7] and China,[8] while deposits of nitrates in arid climates have been discussed by Clark.[9] But invariably the nitrates are accompanied by the chlorides or sulphates of calcium, sodium or magnesium, and these accumulations occur in arid climates where the limited amount of rainfall would prevent rapid bacterial action at the present time, owing to the limiting moisture factor. Thus Ljubavin, in discussing the accumulation in Turkestan, says: "The earth, which is of a pale cinnamon

[3] Hilgard, E. W., ibid., p. 449.

[4] Hilgard, E. W., The Rise of the Alkali in the San Joaquin Valley. California Expt. Sta. Bul., 83: 1–4, 1889.

[5] Headden, W. P., The Fixation of Nitrogen in Some Colorado Soils. Colorado Expt. Sta. Buls., 155 and 178.

[6] Ljubavin, N., Investigations of a Salt-peter Earth from Turkestan (Journ. Russ. Chem. Soc., 16: 617–638); Abstr. in Journ. Chem. Soc. (England), 48: 128, 1885.

[7] Leather, J. W., The Indian Saltpeter Industry. Pusa Research Institute Bul., 24 (1911), 1912.

[8] King, F. H., Farmers of Forty Centuries, pp. 251–254.

[9] Clark, F. W., Data of Geochemistry. U. S. Geol. Survey Bul., 491: 241–246.

color, is dry and can be readily pulverized between the fingers." The 10.61 percent of nitrates of sodium, potassium and magnesium are accompanied by 12.90 percent sodium chloride, 3.25 percent gypsum, and 0.66 of magnesium sulphate.

In our extensive investigations[10] at the Utah Station regarding the production of nitrates in arid soils, we failed to find any evidence confirming the conception that nitrification takes place with great intensity in arid soils. Notwithstanding the common conception we found[11] that: "The average measurable amount of nitric nitrogen formed during a year, which can be clearly attributed to the formation under the influence of irrigation water, is only 28 pounds under the most favorable treatment with water," while Warrington[12] estimates that in 1880–81 89.5 pounds of nitric nitrogen and in 1881–82 86.5 pounds of nitric nitrogen were formed in the Rothamsted soils under humid conditions. Since our results were so diametrically opposed to the common conception, we were led to make a critical analysis of the situation to locate if possible the discrepancy. It appeared to us that there was either (1) some essential fault in our work, since the soil upon which we were working was ideally adapted to bacterial activity and the limiting moisture factor had been removed by irrigation; or (2) the common assumption that nitrification takes place rapidly in arid soils was wrong. An examination of our own work failed to locate an essential error in method, and the large number of determinations precludes the possibility of error of analysis, therefore consideration of the situation led to the critical examination of Headden's results, as previously reported,[13] and finally to the conclusions embodied in this paper.

The Accumulation of Nitrates in Arid Soils.

It is thus seen that the conception that nitrification takes place with great intensity in arid climates rests primarily upon the observation that in certain arid soils there occur accumulations of nitrates in the surface soils. It must be noted, however, *that these accumulations of nitrates always occur with accumulations of other water-soluble salts.*

[10] Stewart, Robert, and Greaves, J. E., A Study of the Production and Movement of Nitric Nitrogen in an Irrigated Soil. Utah Expt. Sta. Bul., 106, 1908; Centralbl. f. Bakt., Abth. 2, 34: 115, 1912.

[11] Stewart and Greaves, Centralbl. f. Bakt., Abth. 2, 34: 128.

[12] Warrington, Robert, Six Lectures on the Investigations at Rothamsted Experimental Station, Delivered under the Auspices of the Lawes Agricultural Trust. U. S. Dept. Agr., Office Expt. Sta. Bul., 8: 72, 1892.

[13] Stewart, Robert, and Greaves, J. E., The Movement of Nitric Nitrogen in Soil and Its Relation to "Nitrogen Fixation." Utah Expt. Sta. Bul., 114, 1911.

There are no reported results showing accumulations of nitrates without the presence of these alkali salts. The nitrates and the alkali salts must be associated in some way. The alkali salts must exert a very markedly favorable influence on the process of nitrification or else the nitrates must be derived from the subsoil in the same way as are the alkali salts. Stewart and Greaves[14] have already presented some very good evidence that this latter conception is correct. A critical examination of the results reported by Dr. Headden of the nitrate accumulations in some Colorado soils indicates a close relationship between the accumulation of nitric nitrogen and of chlorine, thus indicating a common origin.

These accumulations of nitrates in alkali soils are attributed by Hilgard to the rapidity of nitrification of the organic matter of the soil at the present time and by Headden to fixation of the free nitrogen of the atmosphere.

In the above discussion it has been clearly pointed out that the accumulation of nitrates is closely associated with the accumulation of alkali. How, then, does alkali accumulate? According to Hilgard, the slow weathering of the rock particles of the soil gives rise to the formation of water-soluble salts, which in a humid climate are washed out through the drainage to the rivers and thus carried to the sea, while in arid climates the rainfall is only sufficient to carry the salts to lower depths where they accumulate.

With the application of irrigation water these salts rise to the surface and on the evaporation of the water the salts remain behind as a white or black incrustation. Why may not the nitrates accumulate in arid soils in exactly a similar way? In some favored sections in the arid West the soil is markedly free from alkali accumulations owing to the well-drained character of the land, the water-soluble salts being washed out and carried to the lower-lying land, where they accumulate. Surely the forces which cause a concentration of the sodium chloride, sodium sulphate or sodium carbonate would also operate with the equally soluble sodium nitrate!

In Utah and some portions of Colorado much of the alkali is of marine origin. In late geological times much of this section consisted of upper continental seas, which received the deposits of silt and sand from the higher land. The waters receiving these deposits were shut off from the ocean and as the water evaporated the salts were deposited. The material accumulated in the inland seas became impregnated with deposits of water-soluble salts. The soil formed from such material must be susceptible to alkali accumulations. Thus

[14] Stewart and Greaves, ibid.

the famous Book Cliffs in eastern Utah and western Colorado, running almost parallel to the R. G. W. Railroad, consist of shale impregnated with layers of water-soluble salts, made up of gypsum, sodium nitrate, sodium chloride, sodium sulphate and the chloride and sulphate of magnesium. The erosion and recession of these cliffs have given rise to a strip of agricultural soils at the base of the cliffs, extending from Helper, Utah, to Palisades, Colorado, a distance of 190 miles, and having an average width of twelve miles. It is in these lowlands that the soil of the Grand Junction district of Colorado and the Green River district in Utah is located. The soils of the Grand Junction district contain accumulations of nitric nitrogen and water-soluble salts, as already reported by Headden.

The soils at Green River, Utah, are identical with those reported by Headden, being formed out of the same material in the same way.[15] A recent examination of these soils gave some very interesting results. The soils examined at Green River, Utah, had been cultivated only three years, prior to which they had been in the virgin condition and had supported only a meager growth of desert vegetation, such as stunted greasewood and shad-scale, the annual rainfall (7.5 inches) not being sufficient for the vigorous growth of vegetation.

TABLE II.—*Water-Soluble Salts at Different Depths in Peach Orchard on Typical Bench Land Soil North of Green River, Emery County, Utah. Results Reported as Percent of Dry Soil.*[16]

Depth of Sample.	Description of Soil.	Total Organic Nitrogen.	Total Water-soluble Salts.	Calcium Sulphate.	Sodium Carbonate.	Sodium Chloride.	Sodium Sulphate.	Magnesium Sulphate.	Nitric Nitrogen.
Feet.		%	%	%	%	%	%	%	*p.p.m.*
1	Formed from shale	0.04	1.83	1.53	0.02	0.02	0.17	0.07	10
2	in place; plowed	0.04	2.38	1.96	0.02	0.02	0.11	0.10	3.0
3	first in 1907; shad-	0.04	2.22	1.63	0.02	0.02	0.16	0.12	3.0
4	scale growth	0.04	2.07	1.52	0.02	0.03	0.23	0.11	3.0
5		0.03	2.86	1.78	0.02	0.04	0.80	0.13	3.0
6		0.04	3.77	1.75	0.02	0.20	1.34	0.07	13.0
Aver.		0.038	2.52	1.69	0.02	0.06	0.45	0.10	6.0

In Table II are recorded the results obtained from an examination of the water-soluble salts.

These results show that these typical soils contain a high percentage of water-soluble salts, which consist largely of gypsum or calcium

[15] Richardson, G. B., Reconnoissance of the Book Cliff Coal Field between Grand River, Colorado, and Sunnyside, Utah. U. S. Geol. Survey Bul. 371: 9.

[16] All results in the following tables are reported in percentages of dry soil, unless otherwise noted.

sulphate. The amount of soluble carbonate is very small, and, while it has been here reported as sodium carbonate, it very probably consists of calcium carbonate. The amounts of sodium chloride and sodium sulphate in the surface foot are very low but increase markedly with depth. The amount of nitric nitrogen in the soil is slightly higher than normal for arid soil, and has a tendency to accumulate in the first and the sixth foot.

An examination of the alkali accumulation on the surface of this soil presents some instructive results, as may be seen by an examination of Table III.

TABLE III.—*Composition of "Alkali" from Surface of Above Soils. Results Reported as Percents of Dry Soil.*

Depth of Sample.	Description of Sample.	Total Organic Nitrogen.	Total Water-soluble salts.	Calcium Sulphate.	Sodium Carbonate.	Sodium Chloride.	Sodium Sulphate.	Magnesium Sulphate.	Sodium Nitrate.	Nitric Nitrogen.
		%	%	%	%	%	%	%	%	*p.p.m.*
⅛ in.	Hard crust	0.068	1.23	0.93	0.04	0.04	——	0.09	——	12.0
surface	Loose salts	——	12.23	1.82	0.05	2.03	5.99	0.56	1.21	2,000
surface	Loose salts	0.030	43.23	1.66	0.06	1.51	39.16	0.50	0.12	200
surface	Loose salts	0.129	7.50	1.31	0.05	3.04	0.53	1.53	0.60	1,000
Aver.			16.05	1.43	0.05	1.65	11.42	0.67	0.49	803

These accumulations were of two kinds,—one in which a hard crust was formed, the other where the material was loose. The hard crust was found to consist largely of gypsum, containing a small amount of other soluble salts, including some nitric nitrogen. The loose material contained much less gypsum but greater amounts of the sulphate and chloride of sodium and was exceptionally rich in nitric nitrogen, two of the samples containing 2,000 and 1,000 parts per million, respectively, of nitric nitrogen, which is equivalent to 1.20 and 0.6 percent of sodium nitrate on the basis of the dry soil. It should, of course, be kept clearly in mind that these accumulations occur only in very small patches. The composition of the water-soluble salts of several other soils representative of the section are reported in Table IV.

It is thus readily seen that the soils of this section are much richer in nitric nitrogen than are the normal soils of the arid region, and that, with the accumulation of the alkali salts at the surface, the nitric nitrogen also increases to a remarkable extent. What is the source of the nitrogen? An examination of the rock material out of which these soils are formed will throw some light on the question. Four samples of material contributing to the formation of the soil in this district were secured and submitted to analysis. The results are recorded in Table V.

TABLE IV.—*Water-Soluble Salts Found in Shale Soils, Characteristic of the Green River District. Reported in Percentage of Dry Soil.*

Depth of Sample.	Description of Soil.	Total Water-soluble Salts.	Calcium Sulphate.	Sodium Carbonate.	Sodium Chloride.	Sodium Sulphate.	Magnesium Sulphate.	Sodium Nitrate.	Nitric Nitrogen.
Feet		%	%	%	%	%	%	%	*p.p.m.*
1	North of Green River, typical soil	1.91	1.33	0.02	0.05	0.23		0.03	42
2	North of Green River, typical soil	2.84	1.78	0.01	0.12	0.59		0.03	44
1	Uniform desert soil west of Green River	2.24	1.82	0.04	0.01		0.18		3
2	Uniform desert soil west of Green River	2.38	1.91	0.04	0.01		0.19		2
1	"Dead soil"	3.17	1.69	0.03	0.10	1.12	0.08		18
2	"Dead soil"	3.14	1.42	0.02	0.14	1.14	0.17		16
3	"Dead soil"	3.68	1.59	0.02	0.25	1.43	0.16		22

TABLE V.—*Water-Soluble Salts in Different Soil-forming Materials at Green River, Utah. Reported in Percentages of Dry Soil.*

Sample No.	Description of Sample.	Total Salts.	Calcium Sulphate.	Sodium Carbonate.	Sodium Chloride.	Sodium Sulphate.	Magnesium Sulphate.	Sodium Nitrate.	Nitric Nitrogen.
		%	%	%	%	%	%	%	*p.p.m.*
1	Salts in gulch in Book Cliffs	22 21	1.54	0.02	3.47	15.30	1.54	0.04	66.0
2	Shale, Book Cliffs	2.5	0.68	0.03	0.09	1.42	.11	0.02	32.0
3	Shale, N.W. of town	1.05	0.12	0.12	0.04	0.56		0.21	354.0
4	Striation of salts in shale	5.19	3.57	0.04	0.06	1.55		0.08	140.0

Sample No. 1 consisted of salts deposited in a gulch at the base of the Book Cliffs. The salts were incrusted on a few inches of soil which had apparently never supported a growth of vegetation of any character. They had apparently been washed from the adjacent cliffs by a recent shower and, on evaporation of the water, deposited on the soil. This material consists largely of sodium sulphate and is rich in nitric nitrogen. No. 2 and No. 3, samples of shale, are exceptionally rich in nitric nitrogen. Sample No. 3 contains 0.035 percent of nitric nitrogen, or 0.212 percent of sodium nitrate, expressed on the basis of the soil itself. The richness of this soil-forming material in nitric nitrogen and its vast extent, extending as it does 190 miles east and west and at least twelve miles north and south, readily accounts for the accumulation of nitric nitrogen in the soil at those

points where the exposed shale causes a concentration of the salts by the movement of the soil moisture.

The question, no doubt, will arise as to why these accumulations should occur only in patches and not be more uniformly distributed throughout the soil? To appreciate this condition, the material out of which the soil is formed should be kept in mind. The term "Book Cliffs" was applied to these cliffs because they resembled a huge book lying horizontally, the strata looking like the leaves of a closed book. Now, when these cliffs receded by erosion, the soil formed was of varying degrees of thickness. At places the undecomposed shale was almost exposed, while at other places it was buried underneath several feet of soil. On the application of irrigation water to the soil, the water would penetrate to the shale and then follow the horizontal strata, carrying in solution the dissolved salts. At the places where the strata were near the surface, the moisture would rise, carrying the salts in solution and on the evaporation of the water the salts would remain behind. In some cases a bog[17] would result at these places and finally an alkali spring.

The shale composing the Book Cliffs is capped by sandstone. East of Green River this sandstane has contributed largely to the soil formation. The results obtained from the analysis of the water-soluble material in this soil are recorded in Table VI.

TABLE VI.—*Water-Soluble Salts in Sandy Soils East of Green River, near Elgin, Grand County, Utah. Reported in Percents of Dry Soil.*

Depth of Sample.	Description of Soil.	Water-soluble Salts.	Calcium Sulphate.	Sodium Carbonate.	Sodium Chloride.	Sodium Sulphate.	Nitric Nitrogen.
Feet		%	%	%	%	%	*p.p.m.*
1	Characteristic peach orchard soil	0.10	0.05	0.03	0.01		2.4
2	Characteristic peach orchard soil	0.20	0.13	0.03	0.01	0.01	2.0
3	Characteristic peach orchard soil	0.33	0.14	0.04	0.06	0.04	4.0
4	Characteristic peach orchard soil	0.51	0.11	0.04	0.06	0.24	4.0
5	Characteristic peach orchard soil	0.89	0.66	0.02	0.01	0.06	2.0

These soils are markedly free from injurious water-soluble salts and the greater portion of the water-soluble material present consists of gypsum. The soils likewise more nearly represent normal arid soils in their nitric nitrogen content, containing, as they do, from 2 to 4 parts of nitric nitrogen per million.

Near this point the Green River has cut through the sandstone into the Mancos shale which lies beneath, thus enabling the investigator

[17] Brown, C. F., and Hart, R. A., The Reclamation of Seeped and Alkali Lands. Utah Expt. Sta. Bul., 111, 1910.

to obtain samples of the sandstone and underlying shale, together with the accumulation of salts from these strata. The analytical results are recorded in Table VII.

TABLE VII.—*Water-Soluble Salts in the Soil-forming Material East of Green River, near Elgin, Grand County, Utah. Reported in Percents of Dry Soil.*

Description of Sample.	Water-soluble Salts.	Calcium Sulphate.	Sodium Carbonate.	Sodium Chloride.	Sodium Sulphate.	Sodium Nitrate.	Nitric Nitrogen.
	%	%	%	%	%	%	*p.p.m.*
Sample salts on bank of river	37.80	1.08	0.03	5.06	30.98	0.11	180.0
Decomposing sandstone	0.56	0.11	0.02	0.16	0.27		29.0
Decomposing sandstone	1.59	0.61	0.02	0.31	0.56		30.0
Shale material under sand	1.93	0.71	0.02	0.24	0.82	0.05	75.0
Crust from ditch	10.83	0.16	0.13	1.11	8.98	0.20	334.0

These results indicate that the water-soluble salts are rich in nitric nitrogen and also indicate quite clearly that the nitric nitrogen occurring in the soil has its origin to a large extent in the underlying decomposing sandstone and shale. Three hundred miles north of this district accumulations of nitrates have recently been discovered[18] which contain 11.12 percent of nitric nitrogen and 30.89 percent potassium. The position of the accumulations indicated clearly that they were due to concentration of the leaching of the surrounding country rock, consisting of red sandstone. The sandstone itself contains 0.127 percent nitric nitrogen and 0.18 percent of water-soluble potassium. It is significant that this sandstone was formed in an upper continental sea, as was the sandstone out of which the sandy soils of Green River are formed. This shows clearly that any of the soils made out of the rocks formed at the time of these upper continental seas, which extend over vast though yet undetermined areas in the arid West, may be susceptible to nitrate accumulations.

About fifty miles northwest of Green River a new irrigation project is just being promoted. An examination of the virgin soil of this district showed that the surface soil contained only very slight traces of water-soluble salts in the surface soil and from 1 to 2 parts per million of nitric nitrogen. At a depth of six feet the water-soluble salt content was 0.46 percent, of which 0.42 percent was calcium sulphate and 0.04 percent sodium chloride, while the nitric nitrogen content was only 1.4 p.p.m. At a depth of 22 feet, *after passing through over ten feet of undecomposed shale,* the water-soluble salt content was 2.22 percent, of which 0.94 percent was calcium sulphate, 1.18

[18] Stewart, Robert, The Occurrence of Potassium Nitrate in Western America. Jour. Am. Chem. Soc., 33: 1952–1953, December, 1911.

percent was sodium sulphate, and 0.03 percent sodium chloride, while the nitric nitrogen content was 22.4 p.p.m. The climate in this section of the state is extremely arid, the rainfall is probably not over 7 inches per annum. These water-soluble salts in this position in a virgin soil could be only of marine origin. It is important to note that the quantity of nitric nitrogen is *over twenty times* greater than in the surface soil. It could not be conceived of as having been formed at the present time. The soil is very deficient in organic matter. It contains only 0.014 percent organic nitrogen. There is very little organic nitrogen to be nitrified, while there is probably not sufficient organic matter to furnish the energy to support the bacterial life necessary to produce the nitrates.

These facts, together with the deficiency in the moisture necessary for bacterial action and the inability of the nitrates to be moved to their present position owing to the absence of the moisture medium, clearly indicate that the nitrates are of remote origin.

The Book Cliffs form the southern boundary of the Uintah Basin, and the soil of the basin is formed from material similar to that which composes the Book Cliffs. Since the opening of this section to settlement, in 1905, there have been hundreds of thousands of acres of land brought under cultivation. Since the soil formed from the weathering of the Book Cliffs on the south is susceptible to nitrate accumulations, it seemed probable that the soil of the Uintah Basin would be similarly susceptible. An examination of the alkali material of this section in 1911 confirmed this view. Three samples of material were obtained: No. 1 is a sample of the surface soil, containing the characteristic black incrustation; No. 2 is a sample of the white salts picked up on a ditch bank which was devoid of any vegetation; No. 3 is a sample of white material oozing out at the base of a piece of upland soil. The salts obtained were picked up at the edge of an alkali spring, due, no doubt, to seepage water from an irrigating ditch on the upland soil. The results obtained in an analysis of the water-soluble material are recorded in Table VIII.

TABLE VIII.—*Composition of Alkali Salts in Uintah Basin. Recorded in Percents of Dry Soil.*

Sample No.	Description of Sample.	Total Water-soluble Salts.	Calcium Sulphate.	Sodium Carbonate.	Sodium Chloride.	Sodium Sulphate.	Nitric Nitrogen.
		%	%	%	%	%	*p.p.m.*
1	Black soil	2.56	0.98	0.38	0.39	0.95	280
2	White alkali	84.78	1.60	0.36	5.19	76.30	544
3	White salts, base of uplands	89.78	3.20	0.36	1.31	83.17	3,360

This alkali material is exceptionally rich in nitrates. No. 3, which represents the drainage from the uplands, especially is of interest, as it indicates clearly that the nitrates are of marine origin.

In Utah County, in an entirely different kind of soil, lying in the Great Basin formed at the time of Lake Bonneville, similar results were obtained. This soil is west of Utah Lake and supports a native desert growth of shadscale and greasewood. At the time of the examination the soil had just been broken and planted to an apple orchard. The soil consisted of a heavy clay layer extending to a depth of about four feet underlain by a coarse sand layer of varying depth. The soil has a gentle slope to the east toward the lake. Three samples of this material were submitted to analysis: a sample of the loose surface soil to a depth of probably one inch, a sample of the clay layer, and one of the underlying sand.

TABLE IX.—*Water-Soluble Salts in Different Soils from Utah County, Utah. Recorded in Percents of Dry Soil.*

	Surface Layer.	Clay Layer, Depth of 4 Feet.	Sand Layer.
Total soluble salts, per cent	1.51	3.02	3.51
Sodium carbonate, per cent	0.039	0.029	0.053
Sodium chloride, per cent	0.600	2.00	0.82
Calcium carbonate, per cent	0.021	0.014	None
Magnesium carbonate, per cent	0.008	0.016	None
Sodium nitrate, per cent	0.135	0.042	0.003
Calcium sulphate, per cent	0.48	0.88	2.38
Magnesium sulphate, per cent	None	None	0.182
Nitric nitrogen, p.p.m.	225.	70.	0.5

These results indicate a marked accumulation of nitrates in the surface soil. The accumulations of water-soluble salts containing nitrates in the clay layer clearly indicates the source of the alkali and also of the nitrates.

In 1905, a careful examination of the soils of the Southern Utah Experimental Farm was made. A critical study of the results of this analysis will be made elsewhere. The chemical composition of the water-soluble salts is indicated in Table X. While this soil contains a high water-soluble-salt content, it would not be regarded as a dangerous alkali soil, owing to the fact that over 80 percent of the water-soluble material is gypsum. It is significant that the nitric nitrogen content of this soil is very high and that there is almost twice as much nitric nitrogen in the tenth foot as in the first foot; as a result of a large number of determinations the total organic nitrogen content was found to be only 0.028 percent.

In 1910, five years later, a second examination was made of the soil of this farm. The results obtained are recorded in Table XI. Again, there is a high soluble content which consists largely of gypsum. There is a marked accumulation of nitric nitrogen in the fourth

TABLE X.—*Composition of the Water-Soluble Salts in the Soils of the Southern Utah Experimental Farm, St. George, Utah, 1905. Recorded in Percents of Dry Soil.*

Depth of Sample.		Total[19] Salts.	Hydrated Calcium Sulphate.	Sodium Chloride.	Sodium Carbonate.	Sodium and Potassium Sulphates.	Nitric Nitrogen.
Feet.		%	%	%	%	%	*p.p.m.*
1	Average of 40 determinations..	1.55	1.34	0.043	0.052	0.193	22.0
3	Average of 40 determinations..	2.67	2.41	0.037	0.052	0.122	14.0
5	Average of 40 determinations..	2.68	2.43	0.033	0.075	0.148	27.5
10	Average of 40 determinations..	2.85	2.47	0.038	0.097	0.120	38.0

foot. Two samples of the water-soluble-salt accumulation on the surface were secured. One of these samples was a hard crust, the other the mealy soil lying underneath the crust. The crust appar-

TABLE XI.—*Composition of Water-Soluble Salts in the Soils of the Southern Utah Experimental Farm, 1910. Recorded in Percents of Dry Soil.*

Depth of Sample.	Description of Sample.	Total[20] Salts.	Calcium Sulphate.	Sodium Chloride.	Sodium Carbonate.	Sodium Sulphate.	Nitric Nitrogen.
Feet.		%	%	%	%	%	*p.p.m.*
1	Average of 9 determinations..	0.71	0.47	0.058	0.040	0.121	19.0
2	Average of 9 determinations..	1.65	1.27	0.041	0.041	0.226	6.0
3	Average of 9 determinations..	2.39	1.85	0.074	0.029	0.351	5.5
4	One determination.....	2.73	2.01	0.07	0.018	0.37	22.9
5	One determination.....	3.14	1.83	0.106	0.011	1.29	9.9
6	One determination.....	2.86	1.63	0.095	0.018	0.18	56.1
Surface	Hard crust.....	13.70	4.68	7.69	0.021		1,132.0
Surface	Mealy soil underneath crust..	6.59	3.09	2.89	0.029		1,298.0
1	Bad lands.....	5.08	1.30	1.24	0.026	1.72	599.0

ently is due to the presence of excessive quantities of gypsum. Both samples are remarkably rich in nitric nitrogen. The mealy portion contains less gypsum and sodium chloride but slightly more nitric nitrogen. It is markedly significant that there are nitrate accumulations in the lower depths of this soil and that the total water-soluble salts and nitric nitrogen also increase with depth, indicating a common marine origin. The characteristic "bad lands" of this district are rich in nitric nitrogen, the first foot of a representative sec-

[19] Includes water of hydration in calcium sulphate.

[20] Does not include water of hydration of calcium sulphate.

tion containing 599.0 parts per million of nitric nitrogen. It is thus seen that in this soil, containing less than 0.04 percent of sodium chloride to a depth of ten feet in 1905, there had been an accumulation of 7.69 percent *at the surface* in spots by 1910. It certainly would be regarded as folly to attempt any other explanation of this accumulation of sodium chloride than by concentration from the lower depth. Will not the same explanation account for the accumulation of the 1,132 parts per million of nitric nitrogen, especially when it is remembered that in 1905 the nitric nitrogen content increased with depth until there was nearly twice as much in the tenth foot as in the first, while the sodium chloride remained practically constant with depth? Is it necessary to assume rapid nitrogen fixation at the present time?

TABLE XII.—*Nitric-Nitrogen Content of Alkali-free Soil and of Soil Containing Alkali. Results Reported as Parts per Million of Nitric Nitrogen.*

No.	Soils Free from "Alkali."	P.P.M.	No.	Soil Containing "Alkali."	P.P.M.
1	Rothamsted soil, after fallow, 1883	1.3	1	Typical shale soil, Green River, Utah	10.0
2	Rothamsted soil, after clover, 1883	2.2	2	⅛ inch crust, soil Green River, Utah	12.0
3	Rothamsted soil, Bokara clover, 1882	1.3	3	Loose salts	2,000
4	Rothamsted soil, vetches	3.8	4	Shale soil	42.0
5	Rothamsted soil, lucern	3.3	5	"Dead soil," Green River	18.0
6	Rothamsted soil, wheat	4.3	6	Decomposing shale, Green River	354.0
7	Utah irrigated alfalfa	0.8	7	Decomposing sandstone, Green River	30.0
8	Utah irrigated potatoes	1.8	8	White alkali, Uintah Basin	3,360
9	Utah irrigated oats	1.5	9	Black soil, Uintah Basin	280
10	Utah irrigated corn	1.5	10	Virgin soil in Utah Co.	225.0
11	Utah irrigated fallow	5.4	11	1st foot, So. Ut. Ex. Farm	22.0
12	Utah dry farming, wheat	0.8	12	10th foot So. Ut. Ex. Farm 1905	38.0
13	Utah dry farming, virgin	1.0	13	Southern Ut. Exp. Farm 1910	1,298.0
14	Utah dry farming, alfalfa	1.8	14	Bad lands of "Dixie," Utah	599.0

In order to bring clearly to mind the discussion in the preceding pages, Table XII has been constructed from the data already presented. This table shows the nitric-nitrogen content of normal soils free from alkali under both humid and arid conditions and also the nitric-nitrogen content of characteristic alkali soils and of the alkali accumulations. In the normal soils free from alkali in no case does the nitric nitrogen exceed 6 parts per million, while in the alkali soil there is never less than *10 parts per million* and in one case the amount rises to 3,360 parts per million.

Bacterial activity in arid soils may not have been very great in the

past, owing to the limiting moisture factor, but certainly there must have been a definite amount of nitrification taking place. The accumulation of alkali in the soils indicates plainly that the nitrates could not have been lost by drainage. The meager growth of desert vegetation and the fact that little of this was removed, prevents the possibility of the loss of much of the nitric nitrogen in this way. It seems clearly possible, then, that the alkali accumulations of the arid West should be accompanied by soluble nitrates formed by slow nitrification during the remote past. And there is no more reason to assume that the accumulations of nitrates in our arid alkali soils indicate rapid bacterial action at the present than there is to assume that the chlorides and sulphates in alkali soils are of recent origin.

The Significance of the Nitrate Accumulations.

Aside from the possibility of injury to vegetation, the nitrate accumulations are of especial significance from other points of view. The results reported indicate quite clearly that the present nitrate accumulations are due in a large measure to the nitrates formed during the remote past and deposited either from the evaporation of sea water or else carried to lower depths in the soil by the limited amount of rainfall. This conception fully accounts for a number of observed facts. Thus, it is well known that alkali land a year or two previous to "going bad" gives an exceptional yield of crops of very luxuriant growth. The movement of the nitrates together with the other alkali salts from the lower depths to the feeding ranges of the plant roots readily explains this phenomenon, the abundant supply of nitric nitrogen giving rise to a corresponding luxuriant growth.

Hilgard,[21] in a number of papers, has called attention to the fact that arid soils have a low organic nitrogen content and yet do not respond readily to nitrogen fertilization. Thus Hilgard[22] says: "Another point of interest in connection with the supply of soil-nitrogen in arid regions has lately been developed by the work of the station. It having been observed that the light sandy or powdery soils, so characteristic of our fruit-growing mesas, are very poorly supplied with humus, the natural inference was that when these otherwise rich soils began to fall short in production, nitrogenous fertilizers were first in order. The recommendations made accordingly, having in a number of cases failed to produce a satisfactory result, the cause was sought for. Investigation revealed the entirely new fact that

[21] Hilgard, E. W., California Expt. Sta. Rept., 1893–94: 66–70.

[22] Hilgard, E. W., The Supply of Soil Nitrogen. California Expt. Sta. Rept. 1894–95: 34.

humus of the arid soils contains on the average more than three times as much nitrogen as does that of the region of summer rains; and that, therefore, the supply of soil-nitrogen is very nearly the same in both regions. . . .

"We may at the same time congratulate ourselves upon the extraordinary fund of fertility existing in such lands, which seems to postpone indefinitely the necessity of the replacement of nitrogen withdrawn by crops. For what is contained in the first foot of soil is but a portion of what we may fairly presume to be present in the entire soil mass reached by the tap-roots of the beet; and at the same time, the supply is being constantly replenished by natural process."

Elsewhere he says:[23] "It is reasonably presumable that the humus so rich in nitrogen will lend itself more readily to the process of nitrification which must precede the assimilation of the soil nitrogen; a conclusion corroborated by the well known abundant occurrence of nitrates in the soils of the arid regions."

His attempt to explain this by the fact that while the humus content of arid soils is very low, it is much richer in nitrogen than is the humus of the humid soils does not appeal to a number of investigators. It is difficult to conceive how the humus of arid soils being exceptionally rich in nitrogen can make a small quantity of such nitrogen equivalent to the much larger quantity contained in the humid soils. Such a soil, for example, as that of the Southern Utah Experimental Farm, would contain only 560 pounds of organic nitrogen in the ploughed surface soil, which would last for less than six years under the maximum production of a 20-ton crop of sugar beets, while humid soil containing 0.4 of 1 percent of organic nitrogen would contain 8,000 pounds of nitrogen in the ploughed surface, sufficient for a 20-ton crop of sugar beets for eighty years. The fact that six crops of sugar beets would completely exhaust this arid soil of its organic nitrogen, while the organic nitrogen of humid soils would supply nitrogen for the same crop for eighty years makes Hilgard's view untenable. The fact that humus in arid soils is richer in nitrogen simply indicates that the organic matter is in a more advanced stage of decomposition. In the decomposition of the organic matter in arid soils the carbon is lost at a far greater rate than is the nitrogen, thus giving rise to a closer carbon-nitrogen ratio, as has already been clearly demonstrated.[24] This failure of Hilgard's hypothesis to account for the observed fact leaves the question open for a new explanation.

[23] Hilgard, E. W., The Relation of Soils to Climate. California Expt. Sta. Rept., 1892–93, and part of 1894: 113.

[24] Stewart, Robert, Quantitative Relationships of Carbon, Phosphorus and Nitrogen in Soils. Illinois Expt. Sta. Bul., 145, 1910.

The occurrence of nitrates in our arid soils, arising from the marine deposits formed by concentration of the waters of the upper continental seas, or the accumulation in lower depths due to the slow nitrification during the past geologic ages, and the failure of the limited rainfall to remove them, readily accounts for the fact observed by Hilgard. The application of irrigation water furnishes a proper medium for the upward movement of the water-soluble salts, including the nitrates. This upward movement of the nitrates accounts, in a large measure, for the nitrogen removed by the crops, and explains why arid soils apparently deficient in nitrogen are enabled to produce such luxuriant crops on the application of irrigation water. Thus, with the soil of the Southern Utah Experiment Farm, as noted above, it may be readily understood why such a soil so poor in organic nitrogen can produce crops when it is noted that the nitrates increase with depth until there is nearly twice the amount in the tenth foot as in the first, and when it is further observed that these nitrates do rise to the surface, as indicated, by the combined forces of capillarity, diffusion, and hydrostatic pressure.

A clear conception of the method of nitrate accumulations in arid soils offers a ready explanation of how certain dry-farm soils[25] which have been cropped for forty years or more are richer in organic nitrogen than are the adjacent virgin soils. The slow formation of nitrates during the past ages and their tendency to accumulate in the lower subsoil offers a ready explanation of this fact. When such arid soils are subjected to cultivation the deeper-rooted plants of an arid region feed to a certain extent upon these nitrates formed during the past ages. The plant uses this source of nitrogen to form organic nitrogen and, on harvesting, the straw is added to the surface soil, thus increasing the organic nitrogen content of the surface soil at the expense of the nitric nitrogen of the under soil.

Conclusions.

The common conception that nitrification takes place with great intensity in arid climates rests primarily upon the observed fact that nitrates tend to accumulate in great quantities in certain arid soils.

These nitrate accumulations always occur in connection *with other water-soluble salts,* such as sodium chloride and gypsum. No nitrate accumulations have been observed in arid soils free from other water-soluble salts. The alkali salts must therefore be intimately asso-

[25] Stewart, Robert, The Nitrogen and Humus Problem in Dry-land Farming. Utah Expt. Sta. Bul., 109 (1909), 1910.

ciated with the nitrates in one of two ways: first, they must exert a markedly favorable influence upon nitrification; or, second, the nitrates, like the other alkali salts, are of remote origin. From the data presented, it would appear that the latter conception is the correct explanation.

The nature of the material out of which many of the soils of Utah and Colorado are formed indicates clearly that the nitrate accumulations found in these soils are undoubtedly of marine origin.

The alkali occurring in many soils of Utah is undoubtedly, in a large measure, of marine origin, formed by the concentration of the waters of upper continental seas, being deposited at the time of the formation of the shale. On the decomposition of this shale in the formation of soil, the alkali has become incorporated with the latter. The passage of the water through the shale structure also washed out the soluble salts and carried them to the lower-lying land.

The presence of the nitrates in the alkali soils of the arid regions, in addition to the possibility of injury arising therefrom, is of significance from other points of view. It is a well known fact that alkali soils a year or so before "going bad" produce a luxuriant growth of plants, which may be accounted for by the movement of the nitrates up to the feeding range of the plants, while a year or so later the salts become so concentrated as to cause the death of the plants.

Arid soils are markedly poor in organic nitrogen and yet the crops produced are excellent. The soils are not "nitrogen hungry." Hilgard has attempted to account for this apparent anomaly by the assumption that since the small amount of humus in arid soils is relatively richer in nitrogen than is the humus in humid soils, this fully compensates for the apparent deficiency in nitrogen. An appreciation of the tendency of the nitrates, formed during the past ages, to accumulate in arid soils offers a better explanation of this fact, and is not open to the mathematical objections that have been raised against Hilgard's assumption.

There is no reason to assume that the accumulation of nitrates in arid alkali soil indicates a rapid bacterial action at the present time. These accumulations indicate a concentration of the nitrates *already in the soil* and formed by slow bacterial action in the remote past. The application of the irrigation water has simply furnished a medium by which the nitrates may move or be moved from one place to another.

This source of nitrogen affords a clear explanation of the fact that in some cases the surface foot of cultivated dry-farm soils is richer in organic nitrogen than is the adjacent soil, as already indicated.

The nitric nitrogen is obtained by the deep-rooted plants from the subsoil, converted into organic nitrogen by the plant, and then added to the surface soil by the plowing under of the straw.

Of course, it is fully realized that there is the possibility of ammonification, nitrification and even nitrogen-fixation taking place, to a certain extent, in some alkali soils at the present time. But it is evident, from the data presented, that the great accumulations of nitrates found in many alkali soils are clearly of remote origin, being concentrated in their present position by the movement of the soil moisture.

Realizing fully that the term "alkali" must be so extended as to not only include the carbonates, chlorides and sulphates, but also the nitrates of the alkali metals, and recognizing clearly the source and method of nitrate accumulations in our arid alkali soils, we are in a position to work intelligently toward a solution of the problems presented by these unusual accumulations. The adoption of the methods of controlling the accumulations of alkali at the surface, suggested by Hilgard over twenty years ago, such as mulching, tillage and proper drainage, will convert the nitrate scourge into a blessing in disguise.

THE INSTRUCTOR AND HIS STUDENTS.

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While the relations which should exist between the instructor and his students should be, and are, the same no matter what the subject presented may be, yet this paper has in mind the instructor and a class of students in agriculture.

The organization of students into classes is intended to economize time. There is no doubt but that the most effective instruction is that given to individual pupils, but where many individuals are to be instructed it would involve the continuous effort of the instructor and the continuous repetition of the same subject matter. While repetition tends to thoroughness yet there will be a maximum number of repetitions at which the instruction reaches its highest degree of thoroughness and after which it will deteriorate. Hence, we have students organized into classes and the instruction given is mass instruction rather than individual.

Mass instruction has its difficulties when we come to analyze the composition of a class. The students in a class in agriculture are all alike in that they are seeking instruction with a view to reaching a definite end, but they are unlike in that they are not all equally interested in every phase of agriculture. Some are intensely interested in anything relating to animals, but care little for those topics which present various phases of horticulture or agronomy. With other pupils the reverse is the case. So it is that the instructor in animal husbandry complains that John Jones has no interest in his work and is about to fail, while the instructor in field crops finds that Jones is his most promising student.

Then, too, the students in a class have different capabilities. Some are by nature quick-witted, apt to see the point and its application, while others of perhaps more mature age do not grasp ideas readily, yet are just as intent upon mastering the subject.

The students in a college class are rarely of the same age, often differing as much as twenty years. These older students doubtless have had much wider experience and possess more knowledge of practical things, although not so apt in mastering text-book knowledge. It is not uncommon to have men in class who have been to the Philippines in government service, or have traveled extensively in other states, or have had wide experience as farmers or stockmen before coming to college.

Almost every agricultural college nowadays has several foreign students in its classes. Men from China, Japan, Philippine Islands, Mexico, and elsewhere are coming to our colleges for education in the theory of agriculture. Many of these speak and understand the English language very imperfectly.

It is, then, with a class made up of such diverse elements that the instructor has to deal. He must fit his instruction to the needs of the least informed of these and at the same time make it worth while for the student of maturity and experience.

Besides this incongruity of members in his class the instructor often finds himself handicapped in various other ways. In the first place the subject matter of agriculture is as yet poorly organized. We are not yet prepared to say what topics need to be elucidated by instruction and demonstration in the class room and laboratory and what ones might well be left for the student to pick up by reading on the side. The instructor does not find a well beaten path which has been straightened and perfected by hundreds who have gone before, but for the most part he must create his own course.

Often the instructor lacks practical experience. This is a most

serious handicap, for the men in classes in agriculture for the most part have had much practical experience and are quick to discover this weakness in an instructor. Agriculture is a practical subject and the man who has had little practical experience should hesitate to undertake the giving of a course involving much practical work.

Another difficulty which the best of instructors has to labor under, especially where classes are large, is lack of intimate acquaintance with his pupils. An instructor may meet in class every day for a whole semester men whom he knows only by name and the character of work which they present. The instructor knows nothing of their previous home life, their preparation for college or what they hope to do after leaving school. Still less may the instructor know of the student's life in college. Instruction could be much better fitted to the student if the instructor had full knowledge of him. The teacher is apt to be influenced by a few personalities in the class who appreciate his efforts and love the work given. With them the instructor becomes intimate and loses sight of the other members of the class, many of whom sadly need his individual attention.

With instructors who have much administrative work to do it often happens that their time is so taken up with routine duties and affairs of administration that they do not have time for adequate preparation for their class work. Every class meeting should be specially prepared for. "I go before my classes sometimes wondering what in the world I am going to talk about," said an instructor. This man had so much to do with the directing of his department that he could not find time to prepare to meet his classes. Obviously he could not do them justice, or hold interest in his subject.

The management of the class room is as important as thorough preparation on the part of the teacher. While thorough knowledge of the subject tends to relieve the instructor of nervousness and makes him feel at ease before his class, a class in disorder will defeat all his efforts. The attitude of the learner has much to do with his learning. The lounger is usually not a learner. The student who has his feet on the back of the chair in front of him is probably dreaming of topics not at all related to the subject in hand. A room in which the seats are in disarray does not have the atmosphere and influence of one in perfect order. A definite assignment of seats to the members of the class helps much in discipline and attention. Instruction is more effective when the front row of seats is fully occupied.

One of the most important factors in good instruction is full confidence between instructor and students. The instructor cannot long distrust the motives of his class without being found out. The in-

structor may be thoroughly informed and be thorough in his methods, but if he has not the confidence and good will of his pupils his work will be greatly discounted. The instructor who is afraid of his pupils cheating and puts in much of his time studying how to defeat their efforts at dishonest work will have less success than if he allowed wholesale cheating.

The bearing of the instructor has much to do with his success. Thorough preparation makes him free from nervousness, dignity without overbearing promotes respect, politeness wins over those who are inclined to be rude and makes firm supporters of the gentlemen in the class. Sarcasm on the part of the teacher is never in place. Charity for the frailties of men is a useful quality in the make-up of the instructor.

ECONOMIC VALUE OF CORN SUCKERS.

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Submitted for publication in November, 1912.

The removal of suckers from the corn plant soon after their development is quite common with farmers throughout the southern states. This practice is largely based upon a widespread notion among corn-growers that if the suckers are allowed to remain they will not only sap the energies of the main plant by taking away from it much needed plant food, but in return will yield little or no grain and that produced of an inferior quality. Many farmers even think that suckers when they yield grain at all bear only a few imperfect kernels on the tassels.

Four years ago the North Carolina Experiment Station began field experiments designed to determine, among other things, if the common belief that the removal of suckers proved beneficial to the crop was true or not. In the studies sixty-eight varieties of corn were used in 1908; sixty-one in 1909; forty-nine in 1910; and eight in 1911. During the first three years each variety was grown, with and without suckers, under four different conditions of soil fertility and of distancing of the hills of corn in the row. In the last year the varieties with and without suckers have been experimented with on seven different soils of different fertility. The gradation in the productivity of the different sets has been held by the use of stable manure and commercial fertilizers. The results of these investiga-

tions are made use of in this paper and the deductions are based thereon.

Chief Factors Influencing the Production of Suckers.

Soil fertility, distance between plants in the row, variety and season are the principal factors influencing the number of suckers produced per plant. Ordinarily, soil fertility and variety are the factors chiefly controllable.

Effect of Soil Fertility.

Under favorable seasonal conditions with a definite number of square feet given to the growth of each plant, the number of suckers developing per plant with the same variety will increase as does the productivity of the soil.

As an average of the results of 1910 with forty-nine varieties, 14.1 times as many suckers developed per acre on land producing 44.8 bushels of shelled corn as were produced where a yield of 12.3 bushels was secured, while in 1911 with eight varieties there were 6.4 times as many where the yield was 35.6 bushels as when 17.5 bushels were produced. Again, in 1911, on land producing twice as great yield of shelled corn per acre as other land all the varieties averaged 6.5 times as many hills bearing suckers as did the less productive land.

Effect of Different Distancing of Plants.

It was found in 1908 that when corn was grown in four-foot rows on land producing an average of 28 to 32 bushels of grain per acre that 48 percent higher proportion of the stalks produced suckers and 73.4 percent more suckers were developed per acre when the spacing of the plants in the row was 30 inches than when the distance between hills was 20 inches. In 1909 and 1910, with the average yields running 38 to 39 and 41 to 48 bushels per acre, the proportion of sucker-bearing stalks was 15.9 and 110 percent higher respectively, and the yield of suckers 14.3 and 71.4 percent more at 30-inch than at 20-inch spacing of the hills in the row. On the poorer land used in the experiments, where the yields varied from 9 to 16 bushels of grain per acre, the proportion of sucker-bearing stalks was higher by 29.8 percent in 1908, 43.5 percent in 1909 and 650 percent in 1910 at 30-inch than at 20-inch spacing; while the percentage increase of suckers on this land for these years was 100, 7.8 and 471 per cent more respectively at 30 inches than at 20 inches between hills in the row.

It should be remembered that as the number of suckers produced is influenced to a considerable extent by the fertility of the soil, the

more square feet given to each plant on good soil, or the wider the space between hills, the distance between rows remaining the same, the higher the proportion of sucker-bearing hills and the greater the number of suckers that may be expected to develop per acre, when the same kind of seed is planted on uniform soil.

Effect of Variety.

The kind of variety plays an important part in determining the number of suckers produced per acre under any given condition. In the results of 1908, of 1910 and 1911, the prolific varieties produced respectively 300, 130.5 and 25.1 percent more hills bearing suckers than did the one-eared varieties when the two types in each year were grown under identical conditions. In 1911, Brake's, a well-known single-eared variety, was exceeded in the production of sucker-bearing hills 54.7 percent by Biggs' Seven-ear, 64.5 percent by Sanders' Improved, 52.6 percent by Weekley's Improved, 32.3 percent by Cocke's Prolific, and 29.7 percent by Hickory King when all were grown on uniform land. As an average of three years' results, the prolific varieties produced 2.6 times as many suckers that bore ears as did the one-eared varieties.

Effect of Season.

Other factors being the same, the more unfavorable the season is for the plants, especially during the early part of the growth of the corn, the smaller will be the number of suckers produced per acre. Under favorable weather conditions during the first half of the growing period, with corn planted on fertile land, a large development of suckers will take place under most southern conditions, and these may, in some cases with a very dry July and August, depress the yield of grain per acre under what it would be were the suckers taken off at the usual time of removal.

Some Characters Affected by Removal of Suckers.

In these investigations, it has been observed that the removal of suckers from the stalks has had, in most cases, a decided influence upon the different characters of the corn plant which contribute to its economic value, such as prolificacy, size of ears, percentage of grain, yield of grain and of stover per acre, etc.

Effect on Prolificacy.

As only results from two years' work (1909 and 1911) have been obtained in determining the effect of the removal of suckers upon

prolificacy in ears, of course definite deductions cannot be made. The results thus far secured, however, quite strikingly show, for a good average season, the lessenng effect on prolificacy of the removal of suckers.

In 1909 there was an average reduction of 46.3 percent in the number of ears produced per stalk by the corn on the plat from which suckers were removed under what they were on the corresponding plat where the suckers were allowed to develop; but in 1911 there was a reduction of the average number of ears per stalk by 7.4 percent by allowing the suckers to remain. It should be remembered, however, that the results of the past year were secured under weather conditions that were abnormal and which were as unfavorable to suckers performing their functions as would probably ever occur in this latitude. The season was favorable, during the early part of the growth of the plants, for the development of a large number of suckers and later on in the growing season it was very dry and the plants suffered greatly for lack of a sufficient moisture supply. For weeks in July and August the leaves of the plants were rolled. It is natural to suppose that, under such adverse conditions, the plants having a large development of suckers would suffer much more than did those from which the suckers were removed, but even with all this disadvantage there was only 7.4 percent reduction in the number of ears per stalk.

As an average of three years' results (1908, 1909 and 1910) with corn planted in four-foot rows, on land averaging in yield 37.7 bushels of grain per acre, 18.1 percent of the suckers produced ears with the hills 30 inches apart in the row and 9.5 percent at 20 inches. On land averaging 13.7 bushels, 2.1 percent of the suckers bore ears at 30 inches and 1.5 percent at 20 inches. It will be observed from these data that from 6.3 to 8.6 times as great percentage of the suckers bore ears on the good land as on the poor land.

Effect on Size of Ears.

With the exception of the results of 1909, the removal of suckers has tended generally to the production of ears of slightly greater length and diameter by the main stalk, the average increase being 3.2 percent in length and 0.8 percent in diameter. This would seem to be what would be expected since it was found that with a favorable season the prolificacy was increased by the unmolested development of suckers.

Effect on Yield of Grain.

The weight of evidence thus far is that, on an average, with the kinds of land used and the types of varieties experimented upon, there is a slight reduction in the weight of grain per stalk by the removal of suckers. There are many varieties, however, in some or all of the different years, that have not conformed to the general average of all the results.

Effect on Percentage of Grain-to-Cob.

For this character, the results of all the tests are in quite marked conformity and present strong evidence that the removal of suckers from their stalks slightly reduces the percentage of grain to cob. On good land, as an average of the results of 1909, of 1910 and of 1911, there was a reduction of 0.47 percent in the percentage of grain-to-ear by taking off the suckers. To appreciate this average difference, it should be remembered that ordinarily the relation between grain and cob is quite constant, being probably less affected by environment than most other characters of the corn plant. During a favorable season, it has been noticed that there was generally a gradual decline, slight but constant, in the percentage of grain-to-cob as the fertility of the land grew less.

Effect on Stover.

With a few individual varietal exceptions, all occurring during the very dry season of 1911, all the experiments have shown on an average without exception that sucker-bearing plants are heavier producers of stover than are plants from which the suckers were pulled in the early stages of their development. As an average of three years' results on the best land where the suckers were chiefly produced, the depression in yield of stover per acre by removal of suckers has been found to be 29.7 percent, notwithstanding the fact that the growth of the suckers diminished the average height of the stalks 3.9 percent.

Effect on Combined Value of Grain and Stover.

By assigning a value of 80 cents per bushel for grain and $8.00 per ton for stover, it has been found that, on an average of three years' results on the better grade of land, that there was a diminishing by 17.7 percent of the combined value of the grain and stover by the removal of suckers from the stalks. Only in one case with the sets in the three years was there a greater value of grain and stover taken together. This occurred in 1910, and may have been due to

the greater damage to the sucker-bearing portion inflicted by a severe wind storm occurring during August of that year. However this may be, it is quite striking that on an average of three years' work with eight to sixty-one varieties in each test more than one sixth of the value of the corn crop was sacrificed by the removal of suckers. From these data it would appear that hundreds of thousands of dollars must be lost annually by the farmers of the southern states in labor and in yield by not allowing suckers to develop to maturity on their corn plants.

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